FINAL TECHNICAL REPORT

FRAMEWORKS AND FACTORS AFFECTING INTEGRATION WITHIN TECHNOLOGY ASSESSMENTS

EXECUTIVE SUMMARY

By

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Prepared for

THE NATIONAL SCIENCE FOUNDATION
GRANT NO. ERS 76–04474

GEORGIA INSTITUTE OF TECHNOLOGY
DEPARTMENT OF SOCIAL SCIENCES
ATLANTA, GEORGIA 30332

1978

NATIONAL SCIENCE FOUNDATION
Washington, D.C. 20550

FINAL PROJECT REPORT
NSF FORM 98A

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PART I—PROJECT IDENTIFICATION INFORMATION

1. Institution and Address	2. NSF Program	3. NSF Award Number
Georgia Institute of Technology Atlanta, GA 30332	Technology Assessment	ERS 76-04474
	4. Award Period From 6-1-76 To 6-30-78	5. Cumulative Award Amount 87,400

6. Project Title

Development of Frameworks for Integrating the Disciplinary Components of Technology Assessments

PART II—SUMMARY OF COMPLETED PROJECT *(FOR PUBLIC USE)*

This project studied the integration of disciplinary contributions within Technology Assessments (TAs). TA is the study of the consequences of technologies and policies for dealing with these consequences. TA users view interdisciplinarity in TAs as highly desirable, yet integration across disciplines remains a problem in TAs. The 24 large scale TAs funded by the National Science Foundation were used as a data base. Information was gathered from interviews with TA producers, independent evaluation of the output of the TAs, and small group experiments in analyzing TA-like problems. The interviews were analyzed both as case studies and as data for quantitative analysis using such techniques as correlation analysis, factor analysis, and causal path analysis. In the course of the project four primary areas of epistemological gaps were identified in TAs: Social impact analysis, speculation about the future, economics, and the use of formal and quantitative techniques designed for TA and similar studies. Likewise four social and intellectual modes of achieving integration were identified: Common group learning, modeling, negotiation among experts, and integration by leader. Factors affecting integration in TAs were identified and studied. In addition to organizational boundary conditions, these are leadership style, team characteristics, bounding, iteration, communications patterns and epistemological factors.

Principal general conclusions are:

1. The project leader should use a democratic style.
2. A stable three to five member core team covering a range of appropriate disciplines should be chosen.
3. It is desirable to settle the limits and form of the study fairly early in the project.
4. Time and resources should be budgeted and used for iteration of the study components and the entire study.
5. All-channel communication within the core team is very desirable.
6. Significant epistemological gaps should be expected and reorganized.
7. A strategy for integration should be developed using some combination of common group learning, modeling, and negotiation among experts.

PART III—TECHNICAL INFORMATION *(FOR PROGRAM MANAGEMENT USES)*

1. ITEM *(Check appropriate blocks)*	NONE	ATTACHED	PREVIOUSLY FURNISHED	TO BE FURNISHED SEPARATELY TO PROGRAM	
				Check (✓)	Approx. Date
a. Abstracts of Theses	✓				
b. Publication Citations				✓	1979
c. Data on Scientific Collaborators	✓				
d. Information on Inventions	✓				
e. Technical Description of Project and Results		✓			
f. Other *(specify)*					

2. Principal Investigator/Project Director Name *(Typed)*	3. Principal Investigator/Project Director Signature	4. Date
Frederick A. Rossini	Frederick A Rossini	3-19-79

Final Technical Report

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This report was prepared for the National Science Foundation under Grant ERS76-04474. Any opinions, findings, conclusions, or recommendations expressed herein are those of the authors alone and do not necessarily reflect the views of the National Science Foundation.

I. INTRODUCTION

Technology Assessment (TA) and interdisciplinary research are topics that have generated considerable attention in the scientific community. TA has been brought to prominence such actions as the creation of the Congressional Office of Technology Assessment. The term "interdisciplinary," reflecting a combination of expertise, has gained notoriety by its association with all manner of studies. This report presents research findings of a study specifically addressed to the process of integrating disparate knowledge sources in the preparation of a TA, viewed as very desirable by TA users (Berg et al., 1978). The data derived primarily from field interviews with the performers of all 24 large-scale, substantive TAs sponsored by the National Science Foundation (NSF) through 1976 and the analysis of project reports. Additional data were gathered from the conduct of small group experiments, modeled on the 24 TA projects.

Taken together, these data indicate that a number of factors bear on interdisciplinary interactions in TA. We have further identified four distinctive approaches to foster TA integration. All this information was integrated in this Executive Summary with other NSF-sponsored TA methodology studies and with the TA literature to highlight our findings and to offer suggestions on how to implement them to produce better integrated studies in the future.

II. TECHNOLOGY ASSESSMENT: A CONCEPTUALIZATION

Technology assessment (TA) is the study of the full range of impacts resulting from the introduction of a new technology or the modification of an existing technology, and of the policy alternatives for dealing with these consequences. Figure 1 schematically illustrates the process of change associated with a technological development. At the same time, it suggests a structure for

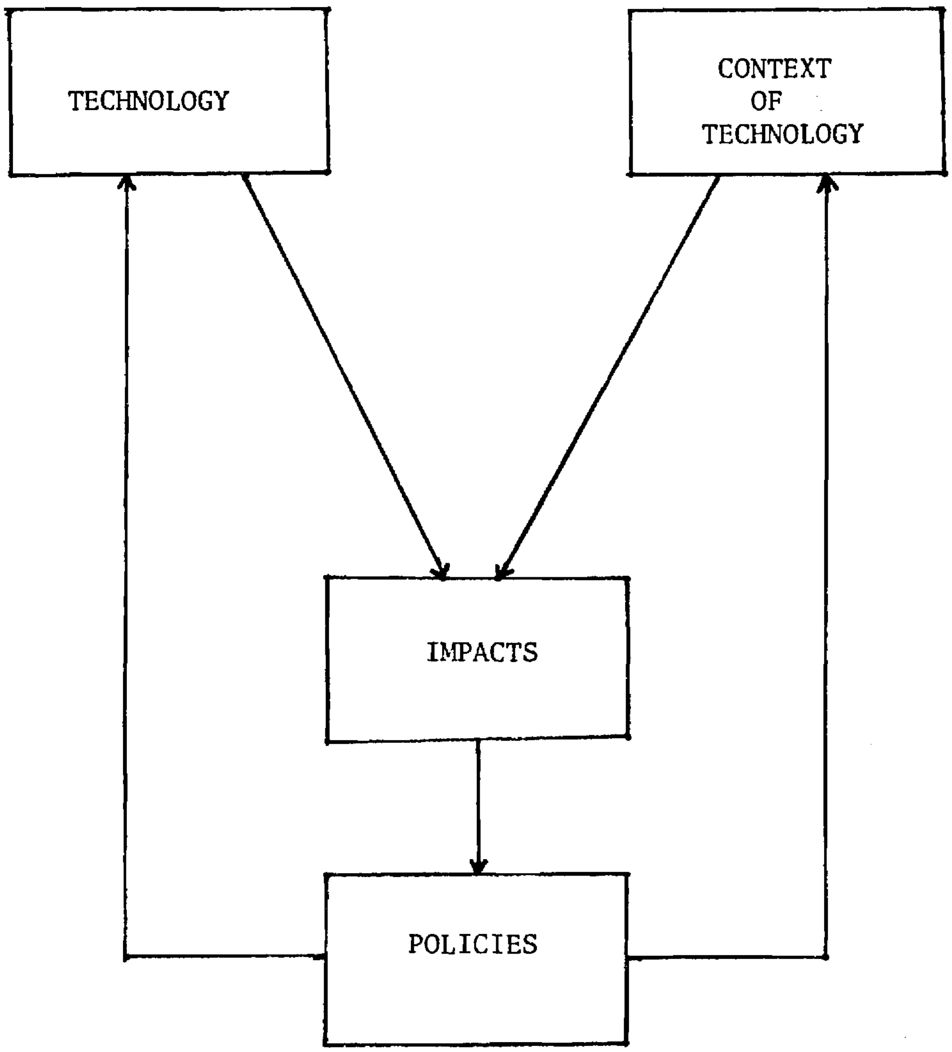


FIGURE 1. A BASIC STRUCTURE FOR A TECHNOLOGY ASSESSMENT

an assessment of that technology. In an assessment, the technology must first be carefully described and its development forecast. Likewise, its context - taken broadly to include social, political, institutional, environmental, and economic components - is to be described and its development predicted. Next in the logic of a TA, come the identification, analysis, and evaluation of the impacts - the results of the interaction between the technology and its context. Lastly, policy alternatives for dealing with the impacts (that may be viewed as desirable, undesirable, or neutral) are identified and their effects on the technology and its context analyzed. The analysis suggested by the flow pattern of Figure 1 is to be repeated (iterated) as many times as necessary to complete the assessment satisfactorily. The TA results should then be communicated to parties who will be affected by the technology and those who will make decisions affecting it. (For more detailed discussions of the TA process, see Armstrong and Harman, 1977, and Porter, et al. 1979, ch. 4 and 5).

TA has a number of properties that make it a complex form of research:

1. It deals with the future and its inherent uncertainties.
2. It is action-oriented, i.e., it is intended to aid in making decisions about the technology being assessed.
3. It properly involves the diverse values and perspectives of the parties at interest in the subject of the assessment.
4. It requires intellectual contributions from a variety of academic and professional disciplines.

The fourth property is at the heart of our concern with achieving a well-integrated TA.

III. INTEGRATION

This study focuses on the influences that produce integration of the disciplinary contributions present in a TA. The premise is that the disciplinary components of a TA should be put together, or integrated, so that the result both reflects interconnections existing between these components and is useful for decision making. Integration, in these terms, is a product of the research process and can most appropriately be determined by studying its output.

In addition to disciplinary integration, there are two other areas in the preparation of a TA where diverse perspectives require integration. One pertains to the diversity of values attendant to any controversial technological development. For instance, power company executives and Sierra Club members are apt to value features of nuclear power plant development in contrasting ways. The procedural structuring of a TA bears upon such value differences in significant ways. For instance, one may bound (i.e., define the domain of inquiry of) an assessment so as to favor one point of view or another. A second such area relevant to integration is relating assessors' interests and capabilities to users' needs. As with the value concerns, utilization demands attention throughout the process of preparing the TA. Issues ranging from the definition of the problem to the methods of analysis to be used require a meeting of the minds between assessors and potential users of their assessment (for detailed treatment of these issues, see Berg et al., 1978). All three types of divergences associated with TAs are likely to occur together. Whatever their disciplinary differences, assessors are typically scientifically oriented, with values tending to the rational and technical; users are likely to be relatively political and bureaucratic. Thus, although our focus is on disciplinary integration, the importance of interrelationships among values and user/assessor differences constitute related areas of concern.

Research on disciplinary integration has been rather limited. Insightful reflection on personal experience is the dominant source of information (c.f., DeWachter, 1976, Petrie, 1976, Walsh et al., 1975 and Weingart, 1977), but some more structured research has been undertaken (c.f., Birnbaum, 1977).

We find a threefold distinction among multidisciplinary, interdisciplinary and transdisciplinary integration to be conceptually useful (Rossini and Porter, 1979).

1. Multidisciplinary integration occurs when the component disciplinary analyses are sensibly ordered, with a suitable introduction prefixed, and appropriate conclusions appended. In addition to this editorial organization, terms and concepts are used consistently throughout the work. In essence, the component analyses stand side by side, coupled externally. Causal explanations are likely to be limited within disciplinary boundaries. Separate authorship of individual components is typical.

2. Interdisciplinary integration occurs when, in addition to editorial organization and consistent conceptual usage, disciplinary analyses serve as substantive, rather than heuristic, inputs to other disciplinary analyses. For instance, an environmental analyses informs and economic analysis in depth, and vice versa; policy options are developed and analyzed in a composite disciplinary fashion. Joint authorship of the study output is the norm.

3. Transdisciplinary integration adds the presence of an overarching theoretical framework that serves to conceptually bind the various component analyses. Interfield theories (Dardin and Maull, 1977) may be a first step towards such transdisciplinary theoretical framework. However, in the present state of the art of technology assessment, and indeed of most cross-disciplinary efforts, this type of integration is an idealized limit.

Accepting that transdisciplinary integration is not yet a realistic option, the choice is between multidisciplinary and interdisciplinary integration. Most TAs probably lie somewhere in between. The case for seeking only multidisciplinary integration incorporates several sound arguments. Academic training and professional experience typically reside in a discipline; therefore, division of analytical labor along disciplinary lines is quite sensible.

True depth of analysis is likely to reside in such disciplinary pieces, and people are likely to prefer working on familiar grounds. On the other hand, we believe the case is even stronger for interdisciplinary integration. Real world cause and effect relationships are likely to cross disciplinary areas of knowledge. Separating impact analyses by discipline is thus likely to miss critical linkages. Furthermore, this approach unfortunately results in restricting the study of higher order consequences (i.e., the impacts of the impacts) to those within a particular area. For instance, strict disciplinary boundaries make it difficult to study political changes due to economic consequences. Such fragmentation would directly threaten the validity of the analysis of cause and effect relationships. From the users' perspective, although it may be convenient for an economist to find all the economic analyses in one place, it appears more important that an impact or policy analysis be presented in an integrated fashion. Indeed, Berg, et al., (1978) found that TA users and performers considered interdisciplinarity to be an important property of a TA.

Having presented our argument in favor of interdisciplinary integration as an appropriate objective for TAs, we now turn to discuss our study of factors which can facilitate such integration. We begin with an account of our research approach.

IV. OUR STUDY STRATEGY

Our study was exploratory in nature. Despite a literature search, we found little in the way of theoretical foundation to justify an hypothesis-testing study design. However, we did uncover useful insights, some directly applicable to the TA situation (Arnstein and Christakis, 1975, stands out as an example). The objectives of the study were twofold: To provide TA practitioners with information on past experiences and recommendations on how to achieve integration; and to develop an intellectual framework to understand integration. Our primary data base was the set of 14 TAs funded by the National Science Foundation as of 1976 at $120,000 or more. This set constituted a complete population. However, our interest was in transferring the lessons of these studies to future TAs.

Table 1 highlights the research strategy we employed. Our general approach can be characterized as an identification of potentially significant features of the TA process, and analysis of how those features related to perceived integration of the TA product. To allow both exploration and some systematic examination of hypotheses, the sample of TAs was divided into two groups of 12. These groups were roughly comparable with respect to performing organization, type of technology, emphasis on technology or policy, and nominal study duration. After the first round of interviews, fairly precise hypotheses were formulated to be probed in the second round interviews. Independent of the interviewing, study outputs (typically in the form of final or draft final reports) were rated by our research team members. Rating on a 1 to 5 scale was performed for comprehensiveness, depth of analysis, editorial integration, conceptual/terminological integration, systemic integration, and overall substantive integration. Editorial and conceptual/terminological integration together approximate multidisciplinary integration. Systemic integration considers the degree to which a common view or representation (e.g., a model) permeates the study, serving to link various sections (below the level of what we called transdisciplinary integration). The judgement of overall substantive integration encompassed the other integration measures, approximating our idea of interdisciplinary integration. To supplement information gained through interviews of some

TABLE 1

REASEARCH STRATEGY AND CHRONOLOGY

1. Initial Phase -- Research Formulation
   --study team reviewed the literature, established study design, generated preliminary hypotheses, and selected the sample of TAs to be studied.

2. First Round Interviews
   --"focused" interviews conducted on-site with participants in 12 TAs.

3. Model Construction
   --based upon the first round interviews, study team formulated more precise hypotheses that combined to offer a model of what affects TA integration; second round interview instrument prepared to probe this model.

4. Second Round Interviews
   --combined structured and open-ended interviews conducted on-site with participants in 12 other TAs.

5. Product Integration Rating
   --two independent readers scored the TA products on various component and overall types of integration, comprehensiveness, and depth of analysis; neither reader had interviewed any member of the project team; (interrater reliability, $\rho = .64$).

6. Small Group Experiments
   --experimental interdisciplinary groups formed on basis of attributes of the 24 TAs were assigned structured "micro-TA" tasks and studied in execution of those tasks; another group session was devoted to the ranking of a set of academic disciplines.

7. Analysis
   --interviews analyzed with product ratings as 24 qualitative case studies, as a quantitative multivariate correlational study, and as a basis for causal modeling; findings compiled with small group results and literature reports.

58 participants in the 24 TAs, we conducted a series of exploratory small group experiments (Chubin et al., 1979). Groups were constituted to simulate the typical disciplinary composition of TA core teams. Two groups composed of faculty, researchers, and graduate students met on three occasions of four hours each. They worked on TA-like problems concerning a physical, a biological, and a social technology. In each session, group members were given instructions to follow a process design to implement one of three distinct approaches to integration that had emerged from the interviews (see section VI of this report). In addition, a third group ranked and debated the intellectual stature of various academic disciplines; this provided a vehicle for expressing some epistemological differences that the interviews had suggested might be important.

Our accumulated evidence thus consisted of the literature analysis, interviews with TA participants, TA report evaluations, and the small group experiments. The interviews were considered first as 24 case studies from which a variety of insights emerged. Second, interview responses were coded and then analyzed quantitatively for the 24 TAs. Second-round projects were analyzed separately first. Only results generally similar to those from all 24 projects taken together were used. The latter are reported herein to take advantage of the greater number of cases. Descriptive tabulations, correlations, and factor analysis afforded insight into the factors influencing integration. These were further explored by constructing alternative models and fitting together the variuos factors affecting integration by means of path analysis. In sum, the results of our efforts are:

- -- a general framework for understanding the process of integration in TA;
- -- identification of factors important in TA integration and an analysis of their interrelationships;

-- a preliminary causal model of the factors affecting integration;

-- identification and analysis of four idealized approaches to the social and intellectual organization of a TA within which integration can take place; and

-- recommendations to practitioners for achieving integration within TAs.

V. FACTORS AFFECTING INTEGRATION

Factors initially postulated as important influences on integration were winnowed through the two interview rounds and subsequent analyses. The resultant factors can be grouped as boundary conditions, or as structural and process factors.

A. Boundary Conditions

Boundary conditions refer to the characteristics of the TA project environment that may influence integration. Factors of interest here include the character of the performing organization and the involvement of consultants and subcontractors in the study itself.

Organizational characteristics that support an integrated TA include organizational committment to interdisciplinary research, capability of attracting and rewarding participants from various disciplines to work on the study, and flexibility in committing time and resources as the study unfolds. In the cases we studied, a combination of small size and flexible structure seemed to provide a desirable environment. These were associated with small (i.e., 30 or fewer professionals) contract research organizations or close-knit institutes in academic institutions. In particular, divisional barriers and strict time accounting practices in some larger contract research organizations caused problems in the conduct of some TAs. Corresponding rigidities concerning narrow disciplinary perspectives and reward structures were sometimes a problem in academic units in universities (see also Dressel et al., 1970). This is not to say, however, that effective TA integration could not take place in less hospitable organizational environments if the TAs were blessed with particularly able project leadership or other highly favorable influences.

A number of the projects studied used subcontractors, consultants, or major participants affiliated with other organizations. Problems due to different organizational goals, interests, and structures can emerge. For instance, academic and contract research norms can clash in an area such as publication objectives. Likewise, a subcontractor who prefers qualitative methods may have difficulty interacting with a quantitatively oriented primary research organization. It was observed that senior level consultants often functioned largely as critics rather than as substantive contributors due to heavy demands on their time. Physical separation, per se, posed another barrier to communication. But difficulties in subcontractor and consultant relationships could be overcome through able project management.

B. Structural and Process Factors

Structural and process factors refer to properties of the project that are more subject to project management control than are the previously mentioned environmental factors. We shall focus on six general factors: leadership characteristics, team characteristics, iteration, bounding, communication patterns, and epistemological factors (i.e., factors to the nature and structure of knowledge).

Leadership characteristics are critical in the conduct of a TA because of the influence of the project leader. Hill's (1970) categorization of three leadership styles appears useful in studying the TA project. The laissez-faire style is non-directive; the leader allows the group to set goals. In contrast, the authoritarian style leader allows the group little or no influence in setting goals and choosing procedures. The democratic style is participatory and group-centered; the project leader encourages mutual relationships with and among the team members. We were able to classify 20 of the 24 project leaders according to style. Table 2 shows the rating of the integration of those TA reports. Projects with a democratic leadership show greater integration.

TABLE 2

LEADERSHIP STYLE AND PROJECT INTEGRATION

Type of Leadership	Number of Studies	Average Overall Substantive Integration of a TA Report (1 to 5 Scale)
Democratic/Facilitating	10	3.27
Authoritarian Laissez-Faire	7	2.14
Laissez-Faire	3	1.93

(Analysis of variance yields $F = 3.22$, $p = .065$. These values give the relative variance between categories to that within categories and its statistical significance. Statistical significance should be considered cautiously here as we are dealing with a population, not a sample. However, we are interested in generalizing beyond that population, but do not have a representative sample.)

Figure 2 suggests possible causal relationships of the structural and process factors with integration: The details of this figure will be developed as we proceed. For now, note that leadership appears to exert both direct and indirect influences on project integration.

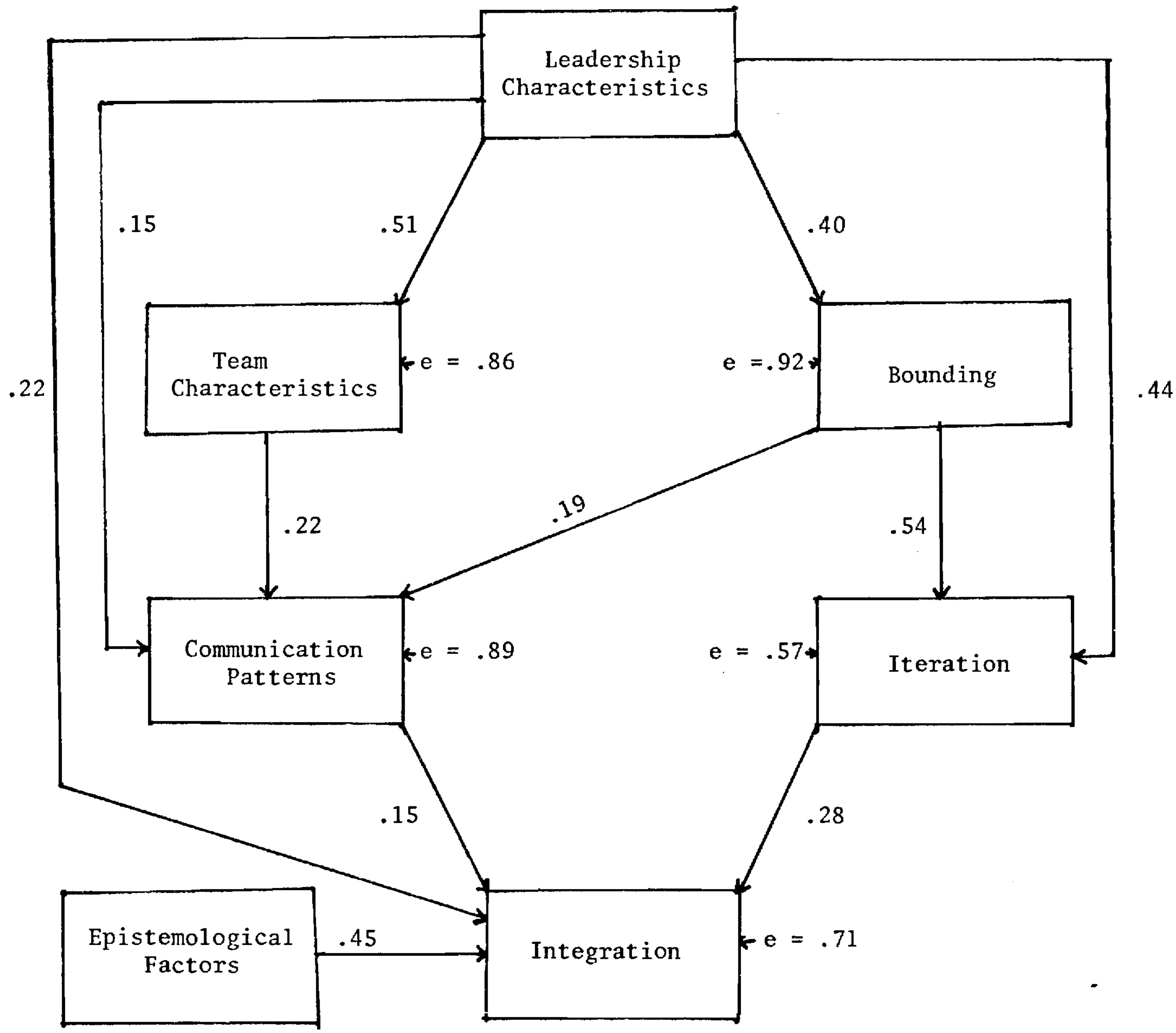


FIGURE 2. <u>A CAUSAL MODEL FOR TA INTEGRATION</u>

The numbers along arrows represent the path coefficients. $e = \sqrt{1-R^2}$, where R is the multiple correlation coefficient. (For treatments of path analysis, see Nie et al., 1975; Duncan, 1975.)

One might suppose (and indeed we did) that persons with broad-ranging backgrounds associated with a "systems" perspective would be preferable as project leaders if one were striving for an integrated study. Our results shown in Table 3 run counter to this - in fact, such persons appear to be associated with the least well-integrated TAs. However, small sample size, difficulties in measuring these concepts, and the likelihood of idiosyncrasies related to personalities and assessment tasks suggests these results be viewed with considerable caution. Nonetheless, they raise questions concerning our image of ideal TA project leaders.

TABLE 3

PROJECT LEADERS" BACKGROUND AND TA INTEGRATION

Disciplinary Background of Leader	Number	Average Overall Substantive Integration of TA Report (1 to 5 Scale)
Social Scientists and Economists	3	4.00
Engineers	2	3.25
Natural Scientists	7	2.57
"Systems," Professional and Mixed Backgrounds	11	2.32

(Analysis of variance yields $F = 1.88$, $p = .17$.)

Team characteristics of interest include the number of core team members, their prior experience in multi- or interdisciplinary projects similar to TAs, and the stability of project leadership and team membership over the course of the study.

The "core team" consists of project participants who are involved in the project as a whole through most of its life. Table 4 suggests that core teams of three to five members typically produce the best integrated projects. We would argue that a core team of one or two members is usually insufficient to effect integration of a complex project, and, on the other hand, a team larger than five members begins to become too large for the intense communication required for effective integration. (The only team studied with more than six core members did a fine job of integration by explicitly attending to this problem.)

TABLE 4

CORE TEAM SIZE AND TA PROJECT INTEGRATION

Number on Team	Number of Teams	Average Overall Substantive Integration (1 to 5 Scale)
1	2	1.00
2	1	2.00
3	3	3.50
4	4	2.63
5	7	2.93
6	5	2.40
8	1	4.50

(Analysis of variance yields $\underline{F} = 1.63$, $\underline{p} = .20$.)

Evidence from the 24 TAs did not show a consistent pattern of importance for prior interdisciplinary experience. In our small group experiments, such experience seemed helpful. It may be that over the life of a typical TA, much learning is possible and the lack of experience can be overcome.

Changes in project leadership and core team membership had a negative effect, particularly on study bounding and iteration. One remedy to turnovers in project personnel is an infusion of additional time and money - either from the performing organization or from the sponsor - to enable satisfactory completion of the work.

Bounding the assessment (i.e., setting the limits and the form of the study) is a process which can continue throughout the study. A certain openendedness appears desirable to accomodate important new developments and insights over the course of the assessment. Satisfactoriness of study bounding, as perceived by the participants, correlated with integration (see Table 5) and with many factors affecting integration.

TABLE 5

EXAMPLES OF SPEARMAN CORRELATIONS OF OVERALL SUBSTANTIVE INTEGRATION WITH SELECTED IMPORTANT VARIABLES

	r_s	p (significance)
Leadership Style	.51	.01
Satisfactoriness of Study Bounding	.43	.02
Number of Times Whole Study Iterated	.50	.02
Character of Communication Pattern During Report Writing	.45	.02
Epistemological Distances Among Team Members (normalized)	.50	.01

Iteration is the process of redoing all or part of a study. It appears to be a vital factor in achieving integration. It is reasonable that substantive interlinking of component analyses will require reworking of those analyses. Indeed our observations on the 24 TAs support this (see Table 5). In this case our finding reinforces the bit of TA folk wisdom that, "First you write the final report and then you do the study." The Environment Protection Agency has specifically required iteration in such studies as the National Coal Technology Assessment. Three iterations appeared to be a useful guidepost - the first being a quick and simple assessment to establish the proper study scope (see Rossini et al., 1976), the second consisting of the major assessment work, the third interlinking and supplementing the component analysis to yield an integrated study.

Two ideal types of communication patterns in TAs can be conceptualized. The "all channel" pattern involves substantial communication between all pairs of core team members. The "hub and spokes" pattern consists of communication links primarily between the team leader and each team member without significant links between pairs of members (Figure 3).

A. All Channel

B. Hub and Spokes

FIGURE 3 COMMUNICATIONS PATTERNS (FOR A CORE TEAM OF FIVE)

Table 6 shows how our characterization of project communication patterns corresponded with the rating of project integration. The desirability of "all channel" communication is especially striking in the crucial final phase of the project. It appears that the "hub and spokes" pattern overloads

TABLE 6

COMMUNICATION PATTERN AND TA INTEGRATION

	Body of Project		Final Phase	
Type of Communication Pattern	Number of Studies	Average Overall Substantive Integration	Number of Studies	Average Overall Substantive Integration
All channel	2	3.50	4	3.80
Intermediate	12	2.96	8	3.25
Hub and Spokes	7	2.29	9	1.92

(Analysis of variance yields for body of project, $\underline{F}$ = 1.08, $\underline{p}$ = .36; for final phase, $\underline{F}$ = 6.75, $\underline{p}$ = .007.)

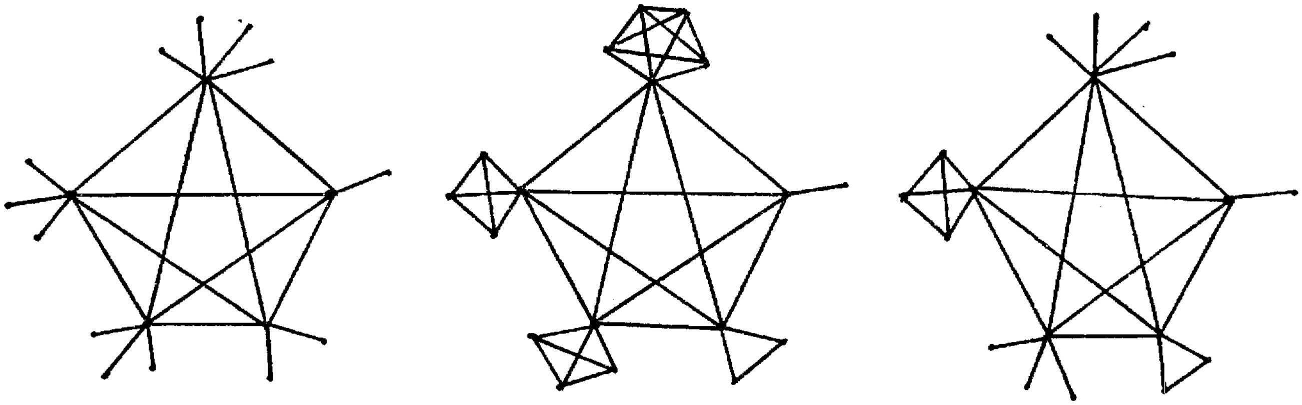
the person at the hub, placing the burden for integration on him or her. In addition, individuals who had worked as "spokes" expressed dissatisfaction with such an arrangement as treating them unprofessionally by discouraging substantive professional interchange with their colleagues. The "all channel" pattern suggests a limitation on core team size, for the number of linkages may become unwieldy as the number of participants increases. Consequently, on large projects one might wish to develop a hierarchy of groups (see Figure 4). On balance, a sensible approach to be what might be called "any channel" - a supportive environment that encourages all communications links between individuals with convergent interests. Figure 5 illustrates such a pattern with links of various strengths.

Epistemological differences among project team members present a potentially serious barrier to TA integration. We specifically addressed such issues in this research, but found it quite difficult to discuss epistemological problems with researchers (much more so than management or communications issues) since no common terminology or set of categories existed. However, in discussions with assessors, we uncovered four specific problem areas that are particularly salient to TA integration:

-- Social Impact Assessment;
-- Data and the Future;
-- Economists;
-- TA Techniques.

The performance of social impact assessment is a serious problem area. Some "hard" science-oriented researchers saw no hope of significant analysis in this area beyond the level of common sense (one principal investigator even referred to social impact assessment as "dreaming"). Others turned to quasi-quantitative techniques to give the form and precision associated with a "harder" methodology. The social scientists involved in TAs tended to be data-oriented and often sought to generate primary social data for the study. The subordinate position of social sciences in the academic pecking order, compounded by the fact that social scientists on the teams were often junior in rank, created tension on several projects.

Another, somewhat related, problem area was the conflict between exclusive reliance on actual data and the willingness to predict (speculate about) the future. Some professionals consider it improper to go beyond currently validated theory and data. (One project leader related in vivid terms the difficulties in dealing with a data-oriented subcontractor unwilling to offer any ex-



All Channel with Wheels | All Channel with All Channels | Combination

FIGURE 4 - POSSIBLE COMBINATION COMMUNICATION PROFILES FOR PROJECT GROUPS - FIVE PERSON CORE TEAM

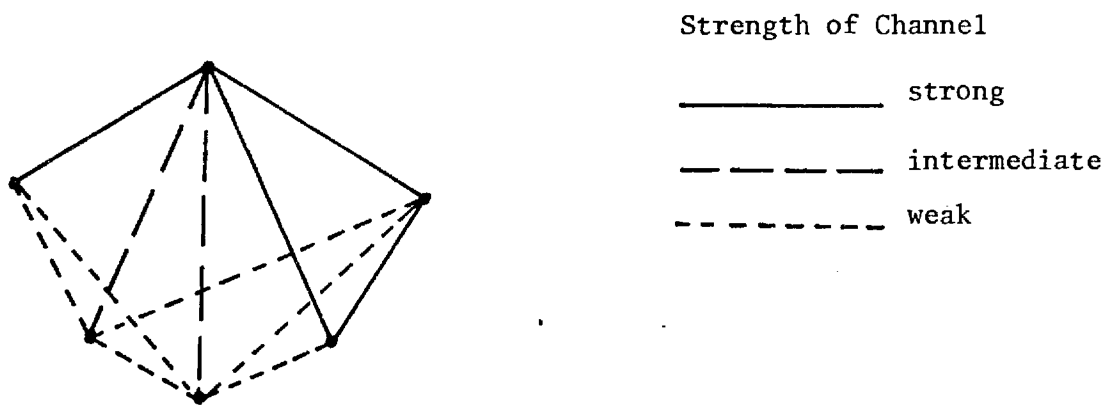


FIGURE 5 - A COMMUNICATION PROFILE IN ONE SUCCESSFUL STUDY

trapolations for the future.) On the other hand, most TA practitioners viewed some form of attempted prediction as necessary to conduct a TA.

Economists were singled out as often frustrating non-economist TA participants. Communication problems included excessive use of jargon, building and use of complex economic models that appeared to have little validity or applicability, and the demand for data that were often unobtainable. Perhaps the most significant problem was the inability of several economists to extend their analysis to areas where monetary values could not be assigned and a corresponding disdain for the importance of such areas.

Finally, there was the question of the use of techniques designed for TA and other future studies, such as Delphi, KSIM, and relevance trees. The avowed purpose of these techniques is to make quantitative and precise what is qualitative and imprecise. Three reactions to these techniques were elicited. The first and most common among our respondents was to ignore them since they recast what is already known, add nothing to the assessment, and give a false impression of quantification. The second tack was to use selected TA techniques sparingly as devices for organizing and improving the presentation and analysis of what is known. The final and least common reaction was to embrace the technique as legitimating the study by making it quantitative and precise. When members of a TA project team differed on this issue, or on the previous three issues, serious difficulties in interrelating analyses typically resulted.

We had postulated that the greater the diversity in disciplinary background among team members, the greater the difficulty in integration. We constructed a simple index of intellectual distance among disciplines to explore this issue (Table 7). Table 5 shows our unexpected finding - the greater the intellectual distance among the core team member, the more substantively integrated the study output. Further, the lower the proportion of "systems" (including

TABLE 7

OUR SCALE OF "INTELLECTUAL DISTANCES" BETWEEN GROUPS OF DISCIPLINES

	1	2	3	4	5	6
1) Social Sciences	0	1	2	2	2	2
2) Economics		0	2	1	0	2
3) Natural Science			0	1	1	2
4) Engineering				0	0	2
5) Systems Professional Mixed					0	2
6) Law						0

multidisciplinary background) people on the core team, the more integrated was the study output. A possible explanation is that the presence of diversity may increase the awareness of the need for integration and for taking measures to achieve it. The ability to interrelate a variety of perspectives in one's own work may not enhance one's ability to integrate it with the work of others. The relative effectiveness of individuals with multidisciplinary backgrounds on TAs merits further study.

We now turn to a model to interrelate these several factors.

C. A Causal Model of TA Integration

One must understand how various factors affect integration before effective action to improve TA integration can be taken. To this end, we analyzed the factors posited as likely to influence integration. We decided to focus upon the structural and process factors (Figure 2). This section describes a causal path analysis of these factors (for treatment of path analysis, see Duncan, 1975; Nie et al., 1975).

The six factors of leadership, team characteristics, bounding, iteration, communication, and epistemological concern were to be related to integration (measured in terms of the rating of overall substantive integration of the project reports). A set of some 21 measured variables were associated with the nominal factor categories. Factor analysis, regression analysis, and judgement by the team members were used in constructing alternative sets of operational factors from the variables. Table 5 indicates selected correlations between integration and certain independent variables, while Table 8 shows the intercorrelation matrix of the factors involved in final causal path analysis model.

TABLE 8

INTERCORRELATIONS OF FACTORS IN THE PATH ANALYSIS MODEL

	Integration	Iteration	Epistemology	Bounding	Communication Patterns	Team Characteristics
ITER	.54					
EPIS	.44	.08				
BOUND	.32	.71	-.16			
COMM	.35	.52	-.06	.36		
TEAM	.22	.23	-.13	.52	.40	
LEAD	.40	.66	-.13	.40	.34	.51

NOTE: For degrees of freedom, ρ = .34 is significant at p = .05 for a one-tailed test. We have also computed the more conservative choice correlation coefficients for these ordinal data, Spearman's r_s, with quite similar results.

In essence, our analysis suggest that the model shown in Figure 2 plausibly fits the empirical results. It is offered as a useful model that can serve as a basis for structuring a project and for studying the process of integration of interdisciplinary research. The model emphasizes the importance of the team leader who can affect the attainment of integration both directly and indirectly. It also indicates separate and important status for the epistemological factors involved in the study. The model suggests that the project leader should attend to bounding and make provisions for scheduled iteration for the study. He or she can and should encourage intra-team communication. However, as mentioned previously, the present data could be found consistent with a number of alternative models. This particular model offers the advantages that it is consistent with our developed hypotheses and our observations.

VI. FOUR APPROACHES TO THE SOCIAL AND INTELLECTUAL ORGANIZATION OF A TA

We assert that the factors discussed in the preceding section affect integration. However, we have said little about the knowledge elements that are to be integrated, and about the specific social structure within which the integration must be effected. It became apparent from our interviews that whatever the abstract merits of analyzing knowledge and social organization separately, in discussing the question of integration they are best treated together. We were able to abstract four ideal types of approaches to the social and intellectual organization of a TA (Rossini and Porter, 1979).

Although these approaches seldom appear singularly in a study, some combination of them appeared in each of the 24 studies. Each of the approaches has advantages; each, disadvantages. We believe that they should be considered as elements in designing study strategy to attain integrated TAs.

A. Common Group Learning

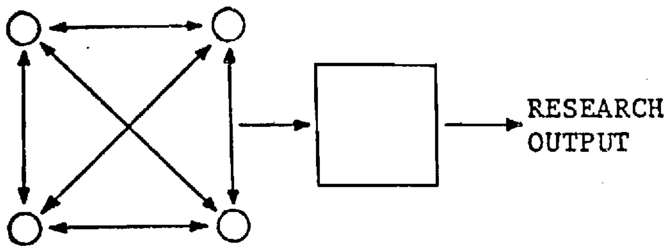
The central feature of common group learning is that the research output reflects the common intellectual property of the entire research group (Kash, 1977; White, 1975). After a research problem is bounded, it is divided into areas based on the expertise and interest of the members of the research group. These individuals prepare preliminary analyses. The group criticizes the individual products. The pieces are then rewritten, almost always by a different individual - often by someone who is not an expert in that area. In addition, the group's productions are criticized by outsiders who are knowledgeable in some phase of the subject matter. This procedure is iterated until the group and its leader feel that the work is sufficiently complete. Figure 6A illustrates common group learning schematically. Note the deemphasis of individual expertise in the final project outcome. Because the status of expert belongs to the group as a whole, the project output is taken from the portion of each team member's knowledge that is common to all. This has the effect of limiting the technical sophistication of the concepts used in the study as these must be familiar to each member of the group. Hence, it tends to decrease the depth of disciplinary analysis.

B. Modeling

In brief, a model is a simplified representation of part of the world. A model is supposed to contain the most important relationships of that part of the world so that its essential workings may be studied. In addition to ab-

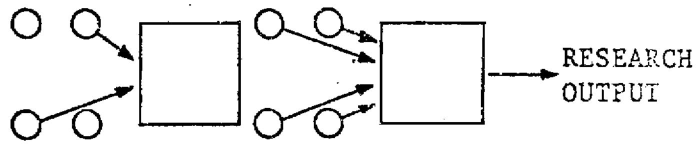
LEGEND: ○ Individuals who possess particular expertise

□ Repositories of knowledge other than individuals



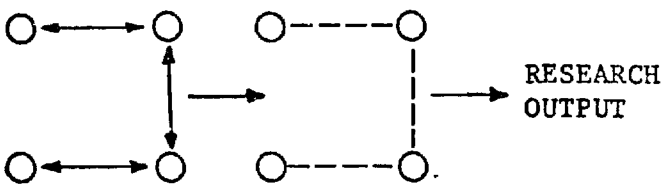
1. Intensive group interaction.
2. Common group knowledge.

A. Common Group Learning



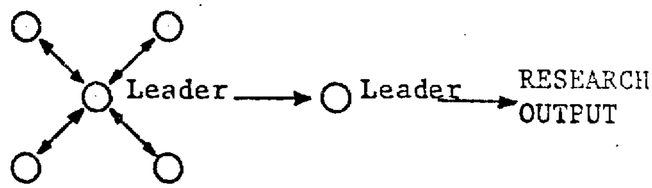
1. Model created by certain individuals.
2. Individuals contribute information to the model and use it in establishing findings.

B. Modeling



1. Pairwise interaction at boundaries between component experts.
2. Better informed and interrelated analysis.

C. Negotiation Among Experts



1. Pairwise interaction only between the leader and other individuals.
2. Leader acquires composite knowledge and synthesizes findings.

D. Integration By Leader

FIGURE 6 Four Approaches to the Social and Intellectual Organization of a TA stract structure, most models require data. Most commonly encountered in the 24 TAs were computerized models dealing largely with economic relationships for which quantitative data could, at least in principle, be obtained (for example, Enzer, 1974; Harvey and Menchen, 1974). Models addressing relationships among persons and institutions tended to take the form of influence diagrams. Modeling is schematically illustrated in Figure 6B. This figure illustrates properties of models which affect their uses as integrative frameworks. The model need not be constructed by the entire research team. It may be imported intact from outside sources. Models tend to narrow the focus of interest. Even models of the entire world consider it as a limited number of interacting factors. These factors are related so that data can be obtained to substantiate the workings of the model. Thus a model can link various forms of data from diverse sources. These data, however, must be compatible or be rendered so by the model. If data do not exist, they need to be invented by some suitable approximation. This usually precludes the use of quantitative and qualitative information in the same model. In summary, models narrow the research focus by excluding nonessential relationships (which is desirable), but also by excluding relevant aspects of the world that do not fit within their framework (which is not desirable). Models favor empirical (data-based) analysis, which is good, but sometimes go to questionable lengths to invent the required data.

C. Negotiation Among Experts

Unlike common group learning and modeling, negotiation among experts was not the dominant framework for integration in any of the TAs studied. In the ideal case, negotiation among experts is a process where, after bounding, the study is divided among the members of the project team on the basis of their individual expertise and disciplinary background. Individual analyses reflect this expertise, incorporating any complex and esoteric theories and approaches that seem germane. The integration of the various analyses then takes place by a process of negotiation.

The subject of the negotiation can be considered as the boundary region and linkages between analyses where their contents substantively affect the other analyses. Effective integration requires the initial analyses to be redone to reflect the inclusion of the findings of the other expert analyses. For example, in TA an economic analysis should be linked to the institutional analysis if it is to be realistic and thus useful. In negotiation among experts, depth and expertise are preserved. There is no question of non-experts redoing an analysis. Figure 6C illustrates negotiation among experts schematically.

D. Integration by a Leader

Integration by a leader relies on the "hub and spokes" communication pattern. The problem is assigned by the leader on the basis of team members' expertise. The leader functions as the sole integrator, and interacts individually with each member of the team to understand and assimilate that member's contribution. The members do not interact extensively among themselves. The leader-integrator develops the interrelationships among the component analyses. See Figure 6D for a schematic representation.

A weakness of this procedure is the enormous demands it places on the leader-integrator (Taylor, 1975). Like common group learning, this framework tends to downplay depth. A single individual (even less than a team) cannot be expected to grasp the details of highly specialized analyses outside his or her area of expertise.

Because of the risk of the non-expert leader dominating expert non-leaders, the leader attempting integration may tend to downplay it in favor of perfunctory editorial revision. The result may lean more toward the multidisciplinary than the interdisciplinary. From the perspective of the leader of an interdisciplinary venture, the other three integration strategies may be more comfortable.

VII. AN IDEALIZED SCENARIO FOR DISCIPLINARY INTEGRATION WITHIN A TECHNOLOGY ASSESSMENT

The previous sections have attempted to explicate the factors that affect the integration of technology assessments. They have drawn heavily on field experience in performing TAs to construct a conceptual framework for understanding integration within TA studies. Clearly, achievement of a well-integrated TA is a complex undertaking. Factors that influence it include characteristics of the task itself, the context in which the assessment is performed, and structural and process considerations in its conduct. All these will be further colored by the values of participants and parties-at-interest and the need to address the interests of potential study users. Given this complexity, it would not be sensible to try to distill the relevant knowledge into any simple "how-to-do-it" rules. However, to convey the essence of our "recommendations," we present an idealized study strategy to facilitate a well-integrated TA.

This scenario is build upon a tripartite structure. First, the organizational boundary conditions will be considered. Second, structural and process factors affecting the overall performance of the study will be introduced. Third, study design issues centering on each of the study components of a TA (Figure 1) will be discussed. For each of the components, we will suggest an appropriate approach (from section VI) and consider how each of the factors affecting integration warrants special consideration. Table 9 summarizes the strategic considerations. (Note again that our recommendations draw upon all sources of information: qualitative and quantitative analysis of the 24 cases, the small group experiments, the literature of technology assessment and interdisciplinary research, and our own insights.)

> We have just received our mandate to undertake the ideal TA. Fortunately the organization that employs us is committed to such interdisciplinary research. Our immediate organizational unit is small and flexible enough to allow us to choose capable and interested professionals to participate in the study without concern for divisional loyalties or billing procedures. Furthermore, the consultants who plan to work with us on the project share our modes of operation, goals, and values.
>
> As project leader and practicing social scientist interested in public policy, I have selected three other core team members based upon their being at ease with team research, and their specific expertise. We include a technical expert in the subject under assessment, an ecologist for environmental analysis, and a person with a business background to lead our economic analyses.
>
> We have sufficient time and resources to have scheduled four iterations (or rounds) of the entire assessment.
>
> 1. Bounding Round -- We begin with a "micro assessment" in which we will briefly (in about three weeks) run through the entire assessment.
>
> 2. Analyzing Round -- We will then divide up the major study elements for an analysis in depth. Each of the core team members will take the lead in part of each study component. He or she will draw upon other professional resources and involve parties-at-interest and other potential users wherever possible. We have then scheduled an informal conference involving both professionals and concerned parties to review our work in this assessment round, and to inform the next round.
>
> 3. Interrelating Round -- This round will involve active interrelations of the component analyses and a more intense evaluation of the proposed
>
> 4. Polishing Round -- After review, a final, less involved iteration will polish the assessment into final form.

TABLE 9

DESIRABLE STRATEGIC CONSIDERATIONS
FOR DISCIPLINARY INTEGRATION IN TA

I. Project Boundary Conditions

   A. Organizational Flexibility and Committment to Interdisciplinary Research Includes

      1. The Ability to Cross Division/Department Lines for Interdisciplinarity

      2. The Ability to Reward Successful Performance of Interdisciplinary Research

      3. The Flexibility in Committing Time and Resources to the Project

   B. Compatibility, or at Least Sympathetic Mutual Understanding, of the Performing Organizations (including consultants) involves the Methods, Goals, and Expectations for the Study.

II. The Project Taken as a Whole - Primarily Dependent on Project Leader

   A. Three to Five Core Team Members are Typically Desirable

   B. The Spread of Disciplinary Expertise on Core Team Should Cover Major Areas of Project Interest

   C. Interest in Performing Interdisciplinary, Team Research Successfully and a Flexible Attitude are Necessary. Prior Experience Core Team Members with One Another and in Team Research TA and TA-Like Projects is Desirable.

   D. Continuity of Project Leadership and Core Team Membership throughout the Life of Project is Very Desirable

   E. Provision for Iteration of the Entire Assessment About Three Times (Three Rounds) is Necessary

III. Specific Components of the Study

   A. Pre-notes

      1. Integration by Leader is not Adequate for Producing Integration on any Large-Scale Study

2. Modeling, by Itself, is not a Sufficient Approach to Accomplish any Structural Component (the technology, the context, impact analysis, policy analysis) but is useful within Components

3. Iteration Takes Place both in Moving from Round to Round and Within each Round. The Description of Strategy for Specific Components (below) is Within a Round and Discusses Iteration in that Context. However, while the Overall Pattern is Similar in all Cases, the Particular Application of the Strategy Depends on the Goals of the Round, in Particular the Desired Depth of Analysis and Comprehensiveness

B. In Studying the Description and Forecast of the Technology and Its Context

1. Common Group Learning Approach is Most Appropriate
2. The Leader Functions to Insure the Development of a Common Knowledge Base in the Group; Leader is a Mediator
3. Any Channel Communications is Most Appropriate; Channels may be of Varying Strength
4. Timely Bounding of Scope and Form of Study is Crucial
5. Iteration Helps to Insure Effective Bounding
6. Group Needs a Common Language and A Speculative Attitude Toward the Future

C. In Impact Analysis

1. Negotiation Approach Most Appropriate
2. Leadership Functions to Achieve Effective Interaction by Pairs and Small Groups; Leader is not an Overall Expert; The Leadership Function is Decentralized
3. Any Channel Communications with Most Communication Taking Place in Pairs and Small Groups is Appropriate
4. Iteration is Directly Provided For in the Negotiation Approach
5. Quality of Bounding Needs to be Emphasized in Getting the Pieces to Fit Together
6. Important Epistemological Gaps to Avoid are Differences in Approaches to Social Impact Assessment, Communicating with Economists, Differences Within the Team in Using Techniques Developed for TA, and Ability to Speculate About the Future

D. In Policy Analysis

1. Common Group Learning is Appropriate for Determining the Scope of the Policy System and Roles of the Actors; Negotiation is Appropriate for Analyzing the Consequence of Policies and Their Interaction

2. Leadership and Communication Patterns are Covered for Common Group Learning in B (above); for Negotiation in C (above)

3. Iteration is Involved in Negotiation; It May Be Used to Reconsider the Bounds

4. The Range of Analysis Needs to be Bounded Rather Early; The Effective Bounding Helps to Relate the Consequences of Policies and Interactions Among Policies

5. The Group Needs a Common Language for Discussing Policies and Some Idea of the Needs of Users.

We now consider how we propose to treat each of the study components as described in Figure 1 - technology description and forecast, context description and forecast, impact analysis, and policy analysis. The treatment of components within each round will depend on the goals of that round, especially the comprehensiveness and depth of analysis required, but the overall patterns will be similar.

Common group learning will be the strategy for treating the technology and context description and forecast. It is important that each core team member possesses a basic understanding of these features to provide a common intellectual basis for subsequent analyses. As project leader, I will follow a democratic approach throughout the project. Leadership is largely a mediating function, but one that exerts considerable leverage over the form and substance of the assessment. We are quite concerned over timely bounding of the main project features at this stage of the assessment. As we advance in understanding the technology and context, we will be revising the preliminary bounding decisions made after the micro-assessment. In general, we will make bounding decisions quite early, but leave these open to change as new insights develop over the course of the assessment. Building an effective "any channel" communication pattern is of high priority at this time. Toward this end, development of a common language by which to describe the technology and its context will take some real effort - given our recognized epistemological differences.

As we move on to impact analysis, negotiation among experts will become the dominant study approach strategy. Here we shall draw on in-depth understanding of various aspects of this sociotechnical system. We are likely to use various models in the impact analysis (e.g., possibly an air pollution model and a decision utility model for the primary developers of the technology in question). For this part of the study we abandon the common group learning strategy; integration is advanced through confronting each analysis with the others as appropriate. As leader, I cannot hope to be the integrating expert at this stage of the assessment process. The primary leadership function will be to ensure the intellectual interaction of the participants. Whole group meetings will give way to pairwise and small group interactions. As the impact analysis proceeds we are likely to readjust certain bounding decisions (e.g., deciding that a particular area does indeed merit detailed analysis). The negotiation mode that we are adopting in the impact analysis will require iteration of component analyses of the round as critical insights are shared. Well before this point we will have ensured that the core team participants have reached agreement on the use of formal and quantitative techniques, that they understand the importance of social impact analysis, and that mutual interchange of ideas with the person in charge of the economic analysis is assured.

We anticipate that policy analysis will involve not only negotiation, but a reintroduction of the common group learning strategy. It is essential that the whole group comprehend the policy system involved, the roles that various actors play in that system, and the full range of alternatives available. As we explore the consequences of particular policy options, it will be necessary to redo impact analyses and to negotiate among the divergent perspectives on the core team. Delineation of the range of policy alternatives to be considered will have been a part of the initial bounding of the TA: It, in particular, will likely require rethinking within each round. In practice we full expect policy analysis to require iteration. For this component of the TA, the assurance of a common language, both within the team and with parties-at-interest and potential users, will require serious attention. However, given our ongoing sensitivity to project management and epistemological concerns, we fully expect to achieve this goal and to produce a well-integrated technology assessment.

VIII. IN CONCLUSION

Our study points in two directions--practice and further study. Our ideal scenario has sketched an assessment strategy that is consistent with the lessons learned in the project. However, it is in no way a unique strategy for achieving integration. Rather, a wide range of variations, depending on the context of the particular assessment, is possible. For success in integration is not due to a single factor or a sequence of steps, but rather to the effective interplay of a variety of factors. Among the most critical of these factors is the character of project leadership. Our evidence strongly supports the need for a democratic/facilitating leadership who encourages "any-channel" intra group communication, especially in the crucial final phase. Iteration of the study is very helpful in achieving integration. Finally, both the maintenance of a broad intellectual capability in the core team and members' striving to achieve integration of their disciplinary perspectives is important. Because social and intellectual elements of a TA are interwined, attention to the appropriate mix of socio-intellectual approaches to integration-common group learning, modeling, and negotiation among experts is necessary.

For future research, we recommend two sorts of studies. One is a series of experimental exercises in using negotiation among disciplinary perspectives to foster integration. For example, cost benefit analysis and social impact analyses of a particular technology could be integrated by interaction among two professionals, and the process chronicled. Another example is integrating policy considerations arising from various perspectives. The results and techniques developed and used in the process might be transferable to other analogous situations.

A second sort of study would entail a comparison among generic approaches to integration. For example, three assessments of the same technology could be conducted under the primary modes of common group learning, modeling, and negotiation. Suitable controls would make other aspects of the studies comparable.

We hope that our research will serve as a guide to actual practice in TA, and to further research in the methodology necessary for handling the enormous complexity inherent in the performance of every assessment.

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FINAL TECHNICAL REPORT

FRAMEWORKS AND FACTORS AFFECTING INTEGRATION WITHIN TECHNOLOGY ASSESSMENTS

REPORT AND APPENDICES

By

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Patrick Kelly, and Daryl E. Chubin

With

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Prepared for

THE NATIONAL SCIENCE FOUNDATION
GRANT NO. ERS 76–04474

GEORGIA INSTITUTE OF TECHNOLOGY
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1978

Final Technical Report

FRAMEWORKS AND FACTORS AFFECTING INTEGRATION WITHIN TECHNOLOGY FRAMEWORKS

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This report was prepared for the National Science Foundation Under Grant ERS76-04474. Any opinions, findings, conclusions, or recommendations expressed herein are those of the authors alone and do not necessarily reflect the views of the National Science Foundation.

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PREFACE AND ACKNOWLEDGEMENTS

With the "first generation" of technology assessments (TAs) completed, the National Science Foundation (NSF) undertook a series of methodological studies to survey the methodological development of TA and to seek directions for future practice.

Martin Jones of the Impact Assessment Institute summarized a number of completed assessments. Vary Coates of George Washington University surveyed TA activity in the Federal Government. Willis Harman and Joe Armstrong of Stanford University undertook an investigation of study strategy. At the University of Michigan Don Michael and Mark Berg studied the utilization of TAs. Hal Linestone of Portland State University analyzed the use of structural modeling of TAs. Aaron Wildavsky of the Russell Sage Foundation dealt with the context of technology assessment. In Dayton in December Joe Martino of the University of Dayton conducted a workshop on the appraisal of technology assessment.

The final project, which we are reporting, was conducted by Fred Rossini and Pat Kelly at Georgia Tech. This project deals with integration of the disciplinary components within TAs. It was undertaken by a team consisting of Rossini, Kelly, and Alan Porter, who worked throughout the project. Daryl Chubin joined the project to take the lead in conducting the small group experiments, and participated in the analysis and final report writing. Stan Carpenter and Andy Lipscomb played major roles in the project's development. We are grateful to John Havick who participated in the earlier phases of the project. In addition, Magoroh Maruyama served as a consultant to the project. He gave us many insights into diverse epistemologies and patterns of social interaction. His work with us on interviews helped improve our understanding of project dynamics. Our oversight committee of Henryk Skolimowski of the University of Michigan, Hugh Petrie of the University of Illinois, Gerry Gordon of Boston University, and Ian Mitroff of the University of Pittsburgh gave valuable assistance. Ian, in particular, made a major contribution to the project by playing a significant role in the design of the small group experiments and leading in the conduct of one session.

We deeply appreciate the support of the National Science Foundation. In particular the encouragement, helpful criticism, and support of Pat Johnson, our project monitor, played a great role in the outcome of this project. Pat and Joshua Menkes of NSF organized a session at the 1978 annual meeting of the American Association for the Advancement of Science in which we presented some of our findings.

The investigators on our companion methodological projects, mentioned above, shared their information freely and offered helpful criticism of our efforts. We benefited from our many formal and informal contacts with them. In addition, Joe Coates of the Office of Technology Assessment shared his incisive views of TA methodology with us.

There are two classes of people without whom the project would have been impossible. These are the participants in TAs who agreed to be interviewed by us. They gave their time and insight without recompense. Their candor about their experiences in the TA process contributed much of what is useful in this project. We cannot thank them enough. The busy professionals who served as subjects in our small group experiments also contributed considerably to the range of experience this report contains. Their capability, flexibility, and professionalism was nothing short of amazing.

Dispite all the assistance we received, the errors, omissions, and lost opportunities remain the property of the authors of this report, particularly FAR. The report represents the opinions of the authors alone, and not those of the National Science Foundation.

I. INTRODUCTION

A. TECHNOLOGY ASSESSMENT

Technology assessment (TA) is the study of the full range of societal consequences of the introduction or modification of a technology, and the policy options available for dealing with those consequences. Characteristically, TA is:

> systematic since it studies the relationship between technology as a cause and its consequences as effects;
>
> higher order analysis since it deals with the "effects of effects." For example, the automobile produced air pollution. This led to governmental regulations for pollution control with associated cost and bureaucracy. These regulations stimulated the development of pollution control technologies. Such higher order effects are often unintended;
>
> interdisciplinary because it studies the full range of consequences and policy options -- economic, environmental, social, institutional, etc. -- and their relationships;
>
> action-oriented in that its results are intended to be used in making decisions about needed change, and the value perspectives of the stakeholders in the technology are involved in the assessment;
>
> future-oriented in that it stresses the analysis of consequences and policies over extended periods of time.

TA was born in the late 1960s of the need for information in government about the long-range and unanticipated consequences of new technologies. This need was clearer than any notion of what the information might consist of, or how it might be produced. In the United States, TA has been almost exclusively the concern of the federal government. Federal efforts began at the National Science Foundation (NSF) in the early 1970s with the funding of a number of TAs at varying magnitudes of effort. NSF remains the lead agency for TA in the Executive Branch. Mission-oriented agencies such as the Energy Research and Development Administration and the Environmental Protection Agency have also funded studies in their areas of interest. The Congressional Office of Technology Assessment (OTA) has begun to function and its first products have appeared. Internationally, TA has been of interest to the member nations of the Organization for Economic Cooperation and Development (OECD) and other developed countries. Current subnational government and private sector interest is not extensive.

Because of their comprehensive nature, TAs are usually performed by a research group composed of representatives of a number of relevant disciplines.

Most assessments are performed by contract research organizations and universities, though OTA has performed a number of studies in-house.

In the process of moving TA from a hope to a body of accomplishment, some learning has taken place. That learning is almost exclusively in the realm of form and technique. Systematic development of theoretical understanding of the technology/society interface has not occurred, and probably will not occur in the near term. Even within the framework of technique and methodology, the question of validating the various alternatives has only now begun to be seriously addressed.

B. TA AS INTERDISCIPLINARY RESEARCH: THE PROBLEM FOCUS

By its very nature, technology assessment requires the contributions of specialists in a variety of academic and professional disciplines. For a number of historical and systemic reasons, the manner in which these contributions are to be made, and how they are to be combined into a coherent and useable whole, have proven to be matters of great difficulty. In order to better understand the distinctiveness -- and the difficulty -- of interdisciplinary research, let us contrast it with the more easily achievable multidisciplinary mode.

> In multidisciplinary research, experts from the relevant disciplines address a common issue using the distinctive methods of their respective fields, and focusing on the questions relevant to their particular disciplinary concerns. Thus economists address the economic aspects of a new highway, while civil engineers consider the roadway itself. The outcome of this process is typically a collection of research pieces connected by their concern with a common problem, and by suitable editorial packaging.
>
> In interdisciplinary research, the goal is an output which deals with a problem from the range of relevant perspectives, but also interrelates these disciplinary components or pieces. For instance, an economist addressing the allocation of water resources in the Western United States would be obliged not only to accommodate the values held by the native Americans in the area, but also the implications of agricultural politics, statutory constraints, etc., to ensure a sound analysis.

One might think of multidisciplinary research as leading to a patchwork quilt, while interdisciplinary research ideally would yield a seamless garment. It is relatively easy to produce multidisciplinary research. A group of "experts" are commissioned to work on a problem independently. When their reports are finished they are editorially integrated by putting the pieces into a reasonable order and writing an introduction and conclusion. Interdisciplinary research, however, involves complexities of a different magnitude. Not only should there be sound disciplinary contributions, but such contributions must also come to terms with one another beyond the level of smooth writing and consistent use of concepts. That is, the resultant analysis must amount to more than the sum of the component disciplinary contributions. Berg et al. (1978) found that 80% of the TA producers and users they surveyed felt interdisciplinarity was either essential or very useful for a TA.

Thus TA is a domain of inquiry where interdisciplinary, rather than multidisciplinary, work is required. Every consideration, every influence, in an assessment invariably affects others, often significantly. For example, the economic and environmental consequences of newly emerging technologies are often interdependent. One cannot be fully understood in isolation from the other. Likewise, available policy options may constrain the future development of a technology. The various aspects of the technology/society interaction dealt with in a TA, if treated in isolation, would present the user with a collection of fragments whose relationships and relative importance would be undetermined. For this collection of fragments to convey valid and useful information, the pieces must be interrelated. In addition, the higher order consequences involve the interactions among diverse lower order consequences. Such higher order analyses require an interdisciplinary mode of inquiry. This is not to suggest that all, or even most, TAs to date have in fact been characterized by this interdisciplinary mode of inquiry.

Since higher order consequences cannot be dealt with in the fragmented TA, such a TA is a less valid guide to the future. It is less useful to decision makers, interest groups, and unorganized lay audiences than a TA whose components are interrelated. Fragmentation may, for example, conceal value conflicts involved in the assessment itself or in the implementation of the technology. Moreover, action on the basis of a fragmented report would lead to a partial coping with one piece of the problem without knowing how a given intervention might affect other parts of the problem -- a potentially costly procedure.

Thus far we have discussed the problem of disciplinary fragmentation and the necessity of TAs being conducted in an interdisciplinary mode. That which makes a TA interdisciplinary we refer to as "integration." A thorough literature search revealed very little specific study of interdisciplinary research beyond the level of intelligent discussions of personal experience (Petrie, 1976: Weingart, 1977: etc.). Thus we were faced with the problem of developing a concept of integration which, on the one hand, made sense in terms of the interdisciplinary research experience of our own team and others, and, on the other, could be dealt with operationally in interviews with TA participants and the analysis of the products of their work. Given an experientially consistent and operationally meaningful notion of integration, we could then study the factors affecting TA integration with the goal of developing procedural frameworks within which it could be improved.

C. THE CONCEPT OF INTEGRATION

Integration within a TA refers to the interrelation of the component analyses of that assessment. In the early phases of our work we identified from a sample of TA reports four types of integration: editorial, conceptual/terminological, systemic, and theoretical. Editorial integration refers to the organization and ordering of material, including such editorial devices as the use of introductions and conclusions. Conceptual/terminological integration refers to the use of consistent terminology with the same meanings throughout the work, and to the avoidance of isolated vocabularies in particular sections. These first two types of integration could obtain in multidisciplinary as well as in an interdisciplinary research. Systemic integration means that a common view or representation permeates the entire study. Various vehicles can be used to achieve systemic integration. One of the most explicit is the formal model, which may form the central integrating core of a study, as it did on a number of the projects we studied (Enzer, 1974; Harvey and Menchen, 1974). Systemic integration does not require the use of explicit computer-based models, however. Unified conceptual frameworks or world-views can also serve this unifying function. At the extreme, there may be an implicit common view of the assessment issue which informs and drives the study. Given the current state of the art, systemic integration represents the maximum expectation for a TA final report. This type of integration is interdisciplinary.

The fourth type, theoretical integration, represents a long-term goal or an ideal limit. There are no comprehensive, transdisciplinary theories of the interaction of technology and society which are sufficiently explicit to offer a theoretical framework for a TA. While theories and theoretical concepts inform TAs in many significant ways, we are not close to the point where theory is a major consideration in assessment. This is unfortunate. The lack of relevant theory accounts for the absence of anything like theoretical integration, as well as the search by assessors in the realm of technique for surrogates to theory in TA.

In our analysis of the TA reports themselves, we considered the first three types of integration, omitting the theoretical. After reviewing the interviews, analyses of reports, and the samll group experiments, editorial and conceptual/terminological integration were merged. We found that conceptual/terminological integration was a category which, while it made sense in the abstract and on a limited reading of assessment reports, proved to be unimportant in our evaluation of reports. Most were thoroughly integrated in this respect, probably because of care in editing. This enhanced category of editorial integration is the first or lowest level of integration, appropriate to both multidisciplinary and interdisciplinary research. The second type of integration in our final configuration is systemic. Systemic integration marks the dividing line between multidisciplinary and interdisciplinary research. Clearly there is no clean edge dividing the one from the other. The best current criteria are the existence of integrative linkages internal to the various parts of the work as well as external to them. For practical purposes the third type, theoretical integration, exists only as an ideal type or limit. It does not presently play a role in TA.

A final comment about our operationalization of integration in analyzing the TA reports concerns two companion concepts: comprehensiveness and depth of analysis. As properties of research efforts, comprehensiveness refers to the range of coverage of the study, while depth of analysis refers to the degree of penetration into the subject matter of the research. Intuitively, there appear to be tradeoffs among integration, comprehensiveness, and depth of analysis, given the finite resources of any single study. For example, it appears harder to integrate a study involving a number of conceptually disparate disciplines than research involving, for instance, only biology and chemistry. Likewise, the complexities involved in deep technical analyses would appear to make integration more difficult than in the case of relatively superficial analyses where editorial skills might be sufficient to insure an integrated narrative. As will be indicated later, we attempted to assess comprehensiveness and depth of analysis as well as integration in the written materials produced by our case study TAs.

D. STUDY STRATEGY

Our study was aimed at understanding the factors affecting the interdisciplinary integration of TAs. The main objective was to provide TA practitioners practical information and recommendations on how to achieve integration. To attain this objective, we needed to operationalize the types of integration discussed previously and find out what factors influenced integration. The latter presented even more of a problem than the former. No strong conceptual or empirical base of understanding of the interdisciplinary research processes pertinent to TAs existed. Consequently, we decided that a predominantly exploratory (rather than a strict hypothesis-testing) study was called for. Our task would be to identify the essential factors that determined how a study team interacted so as to produce a more or less integrated TA. Table 1 summarizes our procedure chronologically.

During the initial phase we searched the literature for influences related to management factors, social-psychological group considerations, and epistemological (i.e., knowledge related) factors. Small group, organizational, management, R & D process, and TA literatures all offered insights, but fell short of providing a coherent theoretical framework to structure this research. At this time we also distinguished between the processes conducive to, and the resultant product indicative of, integrated interdisciplinary work. Information on the processes would be secured via interviews while judgments on the products would be independently made by study team members. The literature did augment our own perceptions of "what mattered" in processes and enabled us to formulate preliminary hypotheses, and, thereby, to construct the first-round interview instrument.

We decided to study all broad-scope TAs funded by the National Science Foundation's (NSF) TA program at a cost of $120,000 or more. There were 24 such studies, generated since 1971, at various states of completion. As such, these constituted a total population. However, we were also interested in the pertinence of our findings to TAs in general. We decided to interview participants on half of these projects, then formulate more specific hypotheses, which would guide our study of the remaining 12 TAs. The sample was split to obtain groups of projects roughly comparable in terms of:

- --the institution performing the assessment -- private contract research firm or university,
- --nature of the topic --"hard" (e.g., geothermal energy) or "soft" (e.g., alternative work schedules) technology,
- --study focus -- problem or policy-focused (e.g., risks to structures from natural hazards) vs. technology-focused (e.g., controlled environment agriculture),

TABLE 1

RESEARCH STRATEGY AND CHRONOLOGY

1. Initial Phase -- Research Formulation (July - September, 1976)
   --study team reviewed the literature, established study design, generated preliminary hypotheses, and selected the sample of TAs to be studied.

2. First Round Interviews (October, 1976)
   --focused interviews conducted on-site with participants in 12 TAs.

3. Model Construction (November, 1976)
   --based upon the first round interviews, study team formulated more precise hypotheses which combined to offer a model of what affects TA integration; second round interview instrument prepared to probe this model.

4. Second Round Interviews (December, 1976 - June, 1977)
   --combined structured and open-ended interviews conducted on-site with participants in 12 other TAs.

5. Product Integration Rating (May - August, 1977)
   --two independent readers scored the TA products on three types of integration, comprehensiveness, and depth of analysis.

6. Small Group Experiments (August - October, 1977)
   --experimental interdisciplinary groups formed on basis of attributes of the 24 TAs were assigned structured "micro-TA" tasks and studied in execution of those tasks.

7. Analysis (August, 1977 - February, 1978)
   --interviews analyzed with product ratings as 24 qualitative case studies, as quantitative correlational study, and as a basis for causal modeling; findings compiled with small group results and literature reports.

--prior experience with technology assessments and prior personal interactions among the assessment team members,

--nominal study duration,

--geographical location (reflecting the realities of travel budgets and time available).

Table 2 indicates the projects studied in both rounds.

The interviews themselves, both first and second round, were conducted by a study team member with relevant TA experience. From one to five participants on each TA were visited (including the principal investigator/project manager), usually individually, in interviews averaging one and one-half hours. On occasions, including all cases where only one project participant, the principal investigator, was interviewed, additional information sources such as briefings or interviews with other members of the performing organization were secured. Nearly all interviewees seemed quite candid, and even eager, to discuss the process of producing the TA. Confidentiality was assured. The interviewers' compatible TA backgrounds, familiarization with project proposals and other information, and the same NSF sponsor also helped. In both rounds, it was easier to discuss group and management behavior than epistemological factors, for which a common vocabulary was lacking.

The first-round interviews used a "focused-interview" approach (Merton, 1956), previously found particularly suitable for interviewing scientists (Zuckerman, 1972; Mitroff, 1 74). We pilot-tested the instrument on Georgia Tech colleagues. After asking the subject for a "thumbnail" sketch of the project, we addressed the following areas at some point in the interview: participants, study development, management, rewards for participation, group interaction, role of the project monitor, involvement of advisors and consultants, efforts to integrate, consideration of study users, character of the performing institution, the role of values in the study, and recommendations as to what was most important.

In contrast, the second-round interviews related to the more specific hypotheses generated on the basis of the first round results. Consequently the interviews included structured, scaled items augmented by more open-ended questions. This instrument was slightly revised after four interviews (labeled A in Table 2). The final interview guide appears as Appendix A.

The TA reports were in various stages of completion. Most had at least reached draft final report status. We operationalized the types of integration and established rating scales as shown in Appendix B. These were used by two independent raters (interrater reliability of ρ = .64 -- Pearson product moment

TABLE 2

TAs FOR FIRST ROUND INTERVIEWS

Controlled Environment Agriculture Technology (International Research and Technology Corporation)

Strategies for Conserving Energy (Braddock, Dunn and McDonald, Inc.)

Advanced Automotive Propulsion Systems (Hittman Associates, Inc.)

Snowpack Augmentation (Stanford Research Institute -- SRI)

Hydrogen Energy Economy (SRI)

Earthquake Prediction (SRI)

Telecommunications-Transportation Interactions (SRI)

Biological Substitutes for Chemical Pesticides (Midwest Research Institute - MRI)

Integrated Hog Farming (MRI)

Conversion From The English To The Metric System (University of Minnesota)

Offshore Oil Operations (University of Oklahoma)

Natural Hazards to Structures (J. H. Wiggins Co.)

TAs FOR SECOND ROUND INTERVIEWS

A.

Geothermal Energy (The Futures Group)

Life Extending Technologies (The Futures Group)

Solar Energy (Authur D. Little, Inc.)

Electronic Funds Transfer (Authur D. Little, Inc.)

B.

Alternative Work Schedules (Haldi Associates)

Hail Suppression (University of Illinois/Illinois State Water Survey)

Remote Sensing of the Environment (University of Michigan/Environmental Research Institute of Michigan)

No Fault Automobile Insurance (Institute for the Future)

Mobile Telecommunications (Cornell University)

Large Scale Air Transport (Gellman Associates)

The Automobile (Columbia University)

Human Rehabilitation Techniques (Texas Tech University) correlation coefficient) who had not interviewed participants in that TA. Ratings were reconciled to yield measures of editorial, conceptual/terminological, systemic, and overall integration, as well as study comprehensiveness and depth of analysis. Evaluations covered the major parts of a TA -- context and forecast, both technical and social; impact analysis; and policy analysis; as well as the study as a whole. The rating form is Appendix C.

To gain insight into the dynamics of interdisciplinary teams, such as those we studied, we added a series of exploratory small group experiments (Chubin, et al., 1978). Groups were formulated to simulate the typical composition of the 24 TA teams -- a five-member team consisting of a physical scientist, an economist, a non-economist social scientist, a "systems" specialist (a researcher identified with studies of systems, a broad systems-like professional orientation, or a multi-disciplinary background oriented toward systems), and an engineer or another "systems" person. The teams consisted of faculty, researchers, and graduate students from the Atlanta area. Two groups met on three occasions of four hours each to work on different TA-like problems. Problems concerned a physical, a biological, and a social technology. In each of these six sessions, the group members were given instructions on group process that were designed to implement three distinct frameworks for obtaining integration which had emerged from the interviews as ideal types of socio-cognitive modes of effecting systemic integration. To explore more explicitly highly focused value divergences, a third group's task was to analyze the relative intellectual stature of various academic disciplines. This provided a vehicle for tapping the epistemological differences among the group members. Appendix D presents a detailed description of the experiments.

Our accumulated evidence consisted of the interviews with participants in the 24 TAs (Appendix E is a profile of respondents), the small group experiences, the report evaluations, and the literature analysis. The interviews were considered first, as 24 qualitative case studies from which a variety of insights emerged. Secondly, the interview responses were coded and analyzed quantitatively, where feasible The second round data were analyzed first. Relationships which appeared important were then analyzed using the data from all 24 TAs. Only when the data agreed in sign and approximate strength did we use it. Some interpretation by interviewers was necessary to code information gained in the first round of interviews and in some topics covered in the second round. Both descriptive tabulations and correlations (Pearson and Spearman, since we were dealing primarily with ordinal data) provided insight into the factors influencing integration. This was further explored by trying several alternative models, fitting together the various factors affecting integration, by means of path analysis based on the correlations. The results of our efforts are:

--a general framework for understanding the process of integration in TA;

--the identification and analysis of four idealized modes of interaction between knowledge and people, identified from the case studies, in which integration could take place;

--the identification of factors important in integration and an analysis of their interrelationships;

--a preliminary causal model of the factors affecting integration.

II. RESEARCH RESULTS

This section is divided into two major parts, Socio-Cognitive Frameworks for Integration and Factors Affecting Integration. The first section treats the interaction of social and knowledge elements in the process of performing TAs. It presents and analyzes as ideal types four forms of this integration which we observed in the study of TA projects. The second part presents a discussion of factors which were hypothesized as significant for integration on the basis of the first round interviews. This discussion includes some quantitative analysis of the interrelationships among the factors, and between the factors and integration, based on data which are largely ordinal. It concludes with the brief treatment of a simple causal model of factors affecting integration.

A. SOCIO-COGNITIVE FRAMEWORKS FOR INTEGRATION

Because interdisciplinary research is team research, entailing social interaction among team members to produce a convergence of disciplinary perspectives, the process of actually achieving integration involves both social and cognitive elements. While one may wish to treat these elements in isolation, in our study of TAs it became clear from interviews with the participants that they were most effectively treated in their interaction. We call these constellations of social and knowledge elements "socio-cognitive frameworks" for integration.

FINDING 1: Four ideal types of socio-cognitive frameworks for integration were isolated and reconstructed. These are: common group learning, modeling, negotiation among experts, and integration by a leader. It was extremely rare for a framework to be used consciously as an integrative device. Indeed it was unusual for a single framework to be used exclusively on a single project.

Discussion: An analysis of the four framework follows:

1. Common Group Learning

Common group learning was developed and used for TA by Don Kash and his co-workers in the Science and Public Policy Program of the University of Oklahoma (See Kash, 1977; White, 1975). The central feature of this approach is that the research output reflects the common intellectual property of the entire research group. In the end there are no experts in any particular part of the research; the group is the expert. After the research problem is bounded by setting the limits and form of the study, it is divided into areas based on the expertise and interest of the members of the research group. These individuals then prepare preliminary analyses. The group reconvenes and criticizes each of the individual products in group sessions. The pieces are then rewritten, almost always by a different individual -- often by someone who is not an expert in the area. In addition, the group's productions are criticized by outsiders who are knowledgeable in some phase of the subject matter. This procedure is iterated until the group and its leader feel that the work is finished. Naturally, the needs of outside sponsors and project schedules drive the group to complete its work at a particular time. Figure 1A illustrates common group learning schematically. Note the de-emphasis of individual expertise in the final outcome of the project.

Because the status of expert belongs to the group as a whole, the project output is taken from the portion of each team member's knowledge which is common to all (i.e., the intersection of the individuals' knowledge). This property has the effect of limiting the technical sophistication of the concepts, theories, and models used in the study as these must be familiar to each member of the group. Hence, it tends to decrease the depth of disciplinary analysis. Locating experts from specific disciplines to be members of the project team is not a high priority in this framework. This approach also means that, in principle, any member of the group can represent the group in activities relating to the research.

2. Modeling

Described loosely, a model is a simplified representation of part of the world. A model is supposed to contain the most important relationships of that part of the world so that its essential workings may be studied. In addition to abstract structure, most models require data. Thus a model of world resource depletion needs some data on what resources exist and how fast they are being used in order to project the world's resource supply in, say, the year 2000.

Most commonly encountered in the 24 TAs were computerized models dealing largely with economic relationships for which quantitative data could, at least in principle, be obtained. Models addressing relationships among persons and institutions tended to take the form of influence diagrams. Modeling is schematically illustrated in Figure 1B.

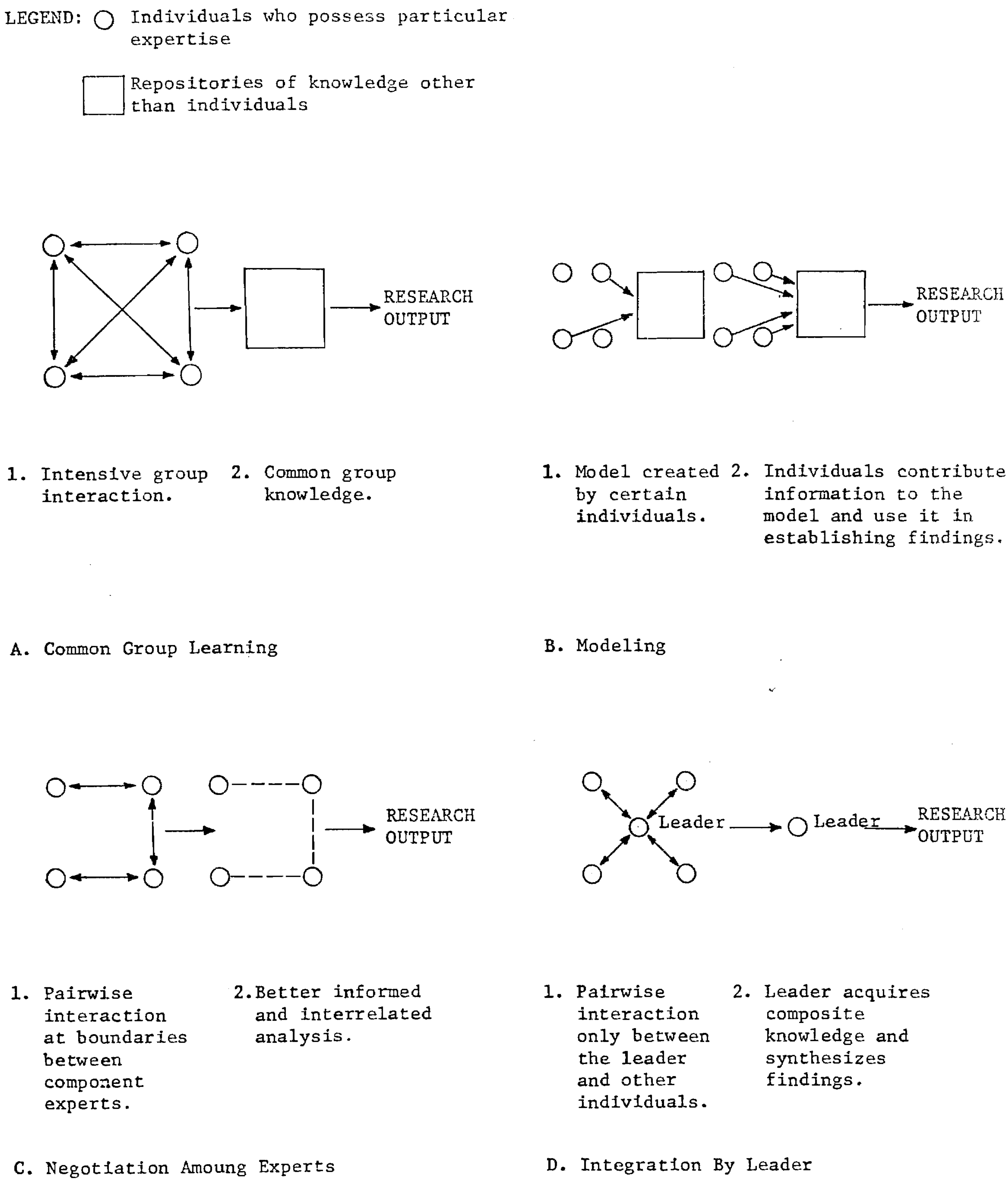


Figure 1. Four Socio-Cognitive Frameworks For Integrating Interdisciplinary Research

This description illustrates some properties of models which affect their use as integrative frameworks. The model need not be constructed by the entire research team. It may even be imported intact from outside sources. Models tend to narrow the focus of interest. Even models of the entire world consider it as a world with only a limited number of interacting factors. These factors are related so that data can be obtained to substantiate the workings of the model. Thus a model can link various forms of data from diverse sources. These data, however, must be compatible or be rendered so by the model. If data do not exist, they need to be invented by some suitable approximation method. This usually precludes the use of quantitative and qualitative information in the same model. Integrating across models does not eliminate such fundamental problems. In summary, models narrow the research focus both by excluding nonessential relationships, which is desirable, and by excluding relevant aspects of the world that do not fit within their framework, which is not desirable. Models favor empirical (data-based) analysis, which is good, but sometimes go to questionable lengths to invent the needed data. Thus, they may be subject to the old criticism of "garbage in, garbage out."

3. Negotiation Among Experts

Unlike common group learning and modeling, negotiation among experts was not the dominant framework for integration in any of the TAs studied. From interviews with participants, it was learned that this strategy appeared in a limited way in a number of studies. In the ideal case, negotiation among experts is a process where, after bounding, the study is divided among the members of the project team on the basis of their individual expertise and disciplinary background. Individual analyses reflect this expertise, incorporating any complex and esoteric theories and approaches which seem germane. The integration of the various analyses then takes place by a process of negotiation.

The subject of the negotiation can be considered as the boundary region and linkages between analyses where their contents substantively affect the other analyses. Effective integration requires the initial analyses to be redone to reflect the inclusion of the findings of the other expert analyses. For example, in TA, an economic analysis should be linked to the institutional analysis if it is to be realistic and thus useful. In negotiation among experts, depth and expertise are preserved. There is no question of non-experts redoing an analysis. Figure 1C illustrates negotiation among experts schematically. Unlike common group learning, negotiation does not render team members expert in every aspect of the project.

Petrie (1976) claimed that knowledge of the meanings of important terms and the observational categories of the other disciplines involved is essential for successful interdisciplinary work. This insight offers an effective starting point for the process of negotiation. Potentially, negotiation can occur within subgroups of any size or even with the participation of the entire team. The practice of negotiation runs more contrary to standard research training than do any of the other frameworks since it involves internal tampering with disciplinary analyses to include other intellectual perspectives.

4. Integration by a Leader

Integration by a leader involves a communication pattern based on the leader as a "hub" and each team member as a "spoke." The problem is divided by the leader on the basis of team members' expertise. The leader functions as the sole integrator, and interacts individually with each member of the team to understand and assimilate that member's contribution. The members do not interact among themselves. The leader-integrator develops the interrelationships among the component analyses. See Figure 1D for a schematic representation.

The weakness of this procedure is the enormous demands it places on the leader-integrator. Does such an "ideal polymath" (Taylor, 1975) exist? Or are the routine demands of leadership such that they prevent any leader from playing such a dominant role? In the case of interaction by a leader, one central problem is to maintain some depth of analysis. Like common group learning, this framework tends to downplay depth. A single individual (even less than a team) cannot be expected to grasp the details of highly specialized analyses outside his or her area of expertise.

Because of the risk of the non-expert leader dominating expert non-leaders, the leader attempting integration may tend to downplay it in favor of mild editorial revision. The result may lean more toward the multidisciplinary than the interdisciplinary. From the perspective of the leader of an interdisciplinary venture, the other three integration strategies may be more comfortable. Common group learning places the burden of confronting an expert upon the whole group. Use of a model may depersonalize confrontation in favor of forcing individuals to meet the information demands of the model. Negotiation among experts suggests confrontation at the boundary between regions of expertise, where more equal conditions may exist.

FINDING 2: Each of the frameworks has strong and weak points. Each is more useful in some situations than others. Strategies for integration might best include a combination of approaches.

Discussion: Common group learning's strength lies in its ability to include a range of disciplines. One price paid for this potential breadth of coverage is a loss of depth. For in the course of a project, each team member cannot master the technical intricacies of disciplines not closely related to his own. Common group learning may be useful as a framework for defining a problem through intense group interaction. Finally it is appropriate for studies up to 6 person -years. As studies become larger, the intense group interaction involved may become cumbersome and difficult to manage.

Modeling's strengths are best applied to problems which are well-defined and lie in a fairly narrow range of closely related disciplines. It can incorporate considerable mathematical sophistication and quantitative data. Any level of effort is possible. If modeling is used in a very broad study or one which is policy related, it is best used in combination with other frameworks.

Negotiation among experts can be used in fairly broad ranging studies, and at considerable depth since it incorporates state-of-the-art expertise. While some definition of the problem is possible, it is not as suited to ill-defined problems as common group learning. The depth it allows is not often attainable in very small studies, and the organizational complexity of very large studies may impede it as an overall strategy.

Integration by leader seems best for small studies. It is limited in breadth and depth of coverage by the enormous demands it makes on the leader.

B. FACTORS AFFECTING INTEGRATION

After the first round of interviews, we hypothesized the effect of a number of factors on integration. Figure 2 illustrates these factors together with their putative linkages. The factors are divided into boundary conditions, structural features, and process features. In the course of our study the factors were operationalized and studied. In this section each factor is treated and a causal model relating some factors to integration is discussed. (Factor is not used in this report to refer to the results of a factor analysis.) Where Pearson product moment correlation coefficients (ρ) and Spearman correlation coefficients (r_s) are given, with few exceptions we listed only values which are ≥ 0.4. All correlation analyses use the project

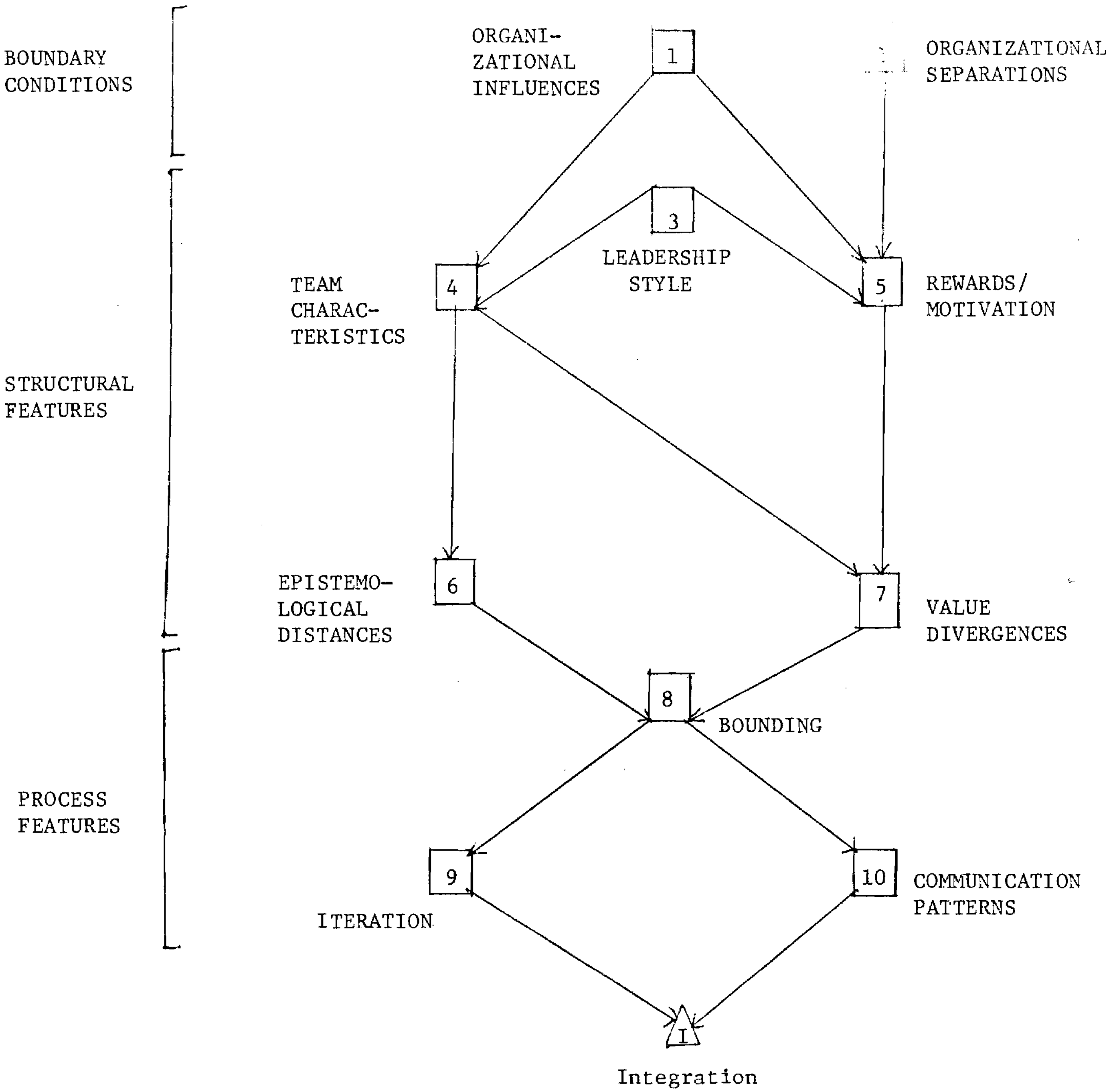


Figure 2 - A Model of Influences Upon Interdisciplinary Integration

NOTE: This schematic figure attempts to show composite direct and indirect influence patterns; it does not distinguish every relationship. For instance, epistemological distances may directly affect communication patterns, but no direct linkage is displayed.

as a unit. Since the 24 projects we studied constitute the universe, significance levels are not a central concern. (However, almost without exception, the correlations listed had significance levels of .05 or less.) What is important is whether the factors are correlated and the direction of the relationship. Our multivariate analyses are discussed in Appendix F.

For integration, which plays the role of a dependent variable in the study, we used the raters' judgement of the "overall substantive integration" of a project's output. This took into consideration all three types of integration we analyzed, with emphasis being placed on systemic integration. Overall substantive integration and systemic integration were highly correlated with $r_s = .80$. Unless otherwise specified, integration, as a variable, refers to overall substantive integration.

One unexpected finding dealt with the correlations among integration, comprehensiveness, and depth of analysis of project output.

FINDING 3: Integration and comprehensiveness are highly correlated, $r_s = .60$, as are integration and depth of analysis, $r_s = .65$, and comprehensiveness and depth of analysis, $r_s = .59$.

<u>Discussion</u>: We anticipated tradeoffs among integration, comprehensiveness, and depth of analysis, but found none overall. While such tradeoffs may have existed in particular projects (which guided our initial impression), a good rating on one meant a good rating on the others. Apparently, none of these factors dominated the efforts of the typical TA team in our population.

We now turn to the individual factors shown in Figure 2.

1. Organizational Influences

The 24 case study TAs examined were conducted in a variety of organizational contexts. Based on initial interviews some of these contexts seemed to be substantially more conducive than others to the sort of interdisciplinary activities that TA requires.

FINDING 4: The organizational contexts seemingly most conducive to the conduct of TAs were (in order of conduciveness):
1. Small contract research organizations (CROs) with low internal barriers
2. University programs or institutes
3. Large CROs with low internal barriers
4. Large CROs with high internal barriers
5. University departments

<u>Discussion</u>: Both academic and contract research organization environments may be characterized by a variety of internal structures (including accounting mechanisms) and incentive and reward mechanisms. The particular mix of these factors may function to facilitate or inhibit the interdisciplinary

participation that TA requires. Given sufficient size, CROs tend to group personnel in units based largely on disciplines or clusters of related disciplines. In addition to these divisional barriers, many CROs require a strict accounting of the individual researcher's time by project charge number. Given the interdisciplinary nature of TA, a unit must thus "buy" the time of researchers in other discipline-oriented divisions.

Since TAs are at this point relatively novel undertakings, they have a way of requiring more time than anticipated. The importance of iteration (redoing the project to reflect what was learned in prior analyses), which was usually not recognized in the original project budget and time schedule, proved to be a particularly troublesome source of pressure in this regard. The organizational barriers, coupled with a strict accountability, often prevented the flexible use of time, and left parts of the TA project with insufficient effort. In a number of cases examined, the principal investigator was burdened with the whole project during its final phases.

Smaller contract research organizations often benefit from a more project-oriented focus with fewer internal barriers and less rigid accounting procedures. There are trade-offs here, however. The smaller CRO may have fewer of the needed professional or disciplinary skills in-house and may be less able to absorb unanticipated cost overruns than its larger counterpart. On balance, however, in the studies we examined, the smaller organization, with fewer internal barriers and more accounting flexibility facilitated the successful conduct of TAs.

Most of the organizational problems in academic environments recounted to us reflected the reality that the disciplinary department is the most significant organizational unit in the university. It controls standards of performance and the rewards allocated to academic personnel (see Dressel et al., 1970). In such environments disciplinary research is more predictably and fully rewarded, while contributions to TAs are typically not seen as an appropriate (and thus rewardable) activity. As a result, we heard stories of problems in acquiring tenure by untenured TA participants. The contracts of some TA participants were not renewed in the middle of the project, though this was unrelated to their performance on that project. In other cases, time-consuming appeal on a case-by-case basis was required by the project leader. Without exception, our case studies of TAs conducted in the academic environment all indicated problems involving the structure of rewards.

A variety of extra-departmental programs or institutes have evolved in the academic world, in part, to overcome these structural and reward-system barriers to interdisciplinary activities. Such units are more conducive to the conduct of TAs. Even so, the extent to which they lack significant control over tenure and promotion continues to be a nagging problem without any visible solution.

Organizational types conducive to TA, as ranked above, has some interesting correlations with other variables relating to the project and affecting its integration.

FINDING 5: The ranking of organizational contexts more conducive to integration correlated (ρ=.49, r_s=.53) with an index of participant motivation with relative rankings as follows:
- +2: interest in TA/interdisciplinary research; interdisciplinary publication
- +1: interest in the topic of the assessment; learning experience; professional "quality" work
- -1: new contracts/grants; "sold time"; job rewards
- -2: disciplinary publication

FINDING 6: The probability that the members of the core team on the TA project had worked together before on a similar project was higher in the more conducive organizational contexts than in the less conducive ones (ρ=.43).

FINDING 7: The extent to which project leaders and participants reported that they enjoyed the project meetings and activities (a facilitating influence in integration)was higher in conducive organizational contexts (ρ=.74 to .84).

FINDING 8: The perception of project participants that epistemological barriers or gaps were significant problems in the project was higher in those organizational contexts less conducive to TA and lower in the more conducive contexts ($|\rho|$ =.46).

FINDING 9: Project teams are more stable (that is less likely to change during the course of the project) in the more conducive organizational contexts (ρ=.57).

FINDING 10: The studies were viewed by the participants as more satisfactorily bounded in the more conducive organizational contexts (ρ=.45).

FINDING 11: The extent and number of times the whole assessment was iterated (a positive influence on degree of integration) was greater in projects conducted in the more conducive organizational contexts (ρ=.42).

FINDING 12: An index of management style, to be described below, which favors a democratic/facilitating style of management over an authoritarian style over a laissez-faire style is correlated with organizational context (ρ=.47).

As boundary conditions the influences of the organizational context on projects conducted within it is mediated by many factors, and thus its effect on integration should be recognized as less direct than most of the other factors.

To summarize this section, the organizational characteristics which set an environment supportive of TA work include the ability to easily involve researchers from various disciplines on the team, organizational commitment to interdisciplinary research, the ability to retain and reward personnel who are contributing to interdisciplinary research (academia is the prime offender), and some flexibility in committing time and resources as the project unfolds (highly structured contract research organizations create the principal problems here). A combination of small size and flexible structure seemed to provide the most appropriate environment for TA in the case studies we undertook. These characteristics were associated with the small, cohesive contract research organization or the close-knit program or institute in the university environment. However, it should be noted that other environments proved quite workable when their inhibiting features were neutralized by particularly able project leadership or by some mix of other influences.

2. Organizational and Physical "Distances"

Ten of the twenty-four TA projects we studied made use of consultants and/or subcontractors, or involved the participation of core team members from diverse organizations. This led us to consider the influence of such "distances" on integration, both in the sense of participants who are separated physically and by distances in their interests, goals, procedures, and professional orientations.

FINDING 13: In this context of extremely small numbers (N=10), there was no significant correlation between the relative "distances" of the members of the core team, consultants, and subcontractors on the one hand, and the integration of project output (or any factor significantly connected with integration) on the other. Nevertheless, the extent and frequency with which this cluster of problems was discussed by those we interviewed leads us to believe that such "distances" are potential problems and that steps should be taken to minimize their counter-productive effect.

Discussion: The information gathered during our interviews indicated that problems with outside consultants and subcontractors were common. Their goals and interests were often significantly different from those characterizing the performing organization. For instance, one mismatch noted was between the academic mode of using time, in which little accounting of hours is kept and work hours often vary considerably from week to week, and the CRO mode, in which time is strictly accounted for and work weeks are essentially constant. Another frequently mentioned mismatch lay in the methodologies used by different, relatively specialized organizations. These organizational "distances", when added to physical separations, diminished participant interaction which (as will be discussed later) contributed to integration.

The use of high-level consultants was also reported by some to be a problem. Because of the heavy demands on their time, such consultants often proved to be unable to function as substantive contributors to the project. Even when such substantive individual contributions were forthcoming, their output, at times, did not relate well with the rest of the project. Typically, the most effective function of high level consultants was that of a critic or kibbitzer.

However, problems caused by such "distances" could be overcome. The potential counterproductive effects of physical and organizational "distances" of core team members and other participants were mitigated in a number of cases by systematically insuring a high level of communication among them. Regularly scheduled meetings, conference calls, and frequent phone contact were the most common devices.

3. Leadership Characteristics

We now shift attention from the more "macro" considerations of organizational context to several structural features of the TA project itself. These include characteristics of project leaders and interdisciplinary teams, motivating influences upon their styles of seeking knowledge, and their inherent values.

An important factor in project management is the style of the leader. Hill (1970;11) notes three leadership styles commonly identified in the literature;

> (1) Non-directive, permissive, a laissez-faire, accommodative or abdicative style where the leader relinquishes any influence in setting group goals to the group; (2) democratic, a participatory, group centered, subordinate centered, employee centered, human relations oriented style where the supervisory allows and encourages a mutual relationship with subordinates; (3) autocratic, authoritarian, boss centered, task centered, production centered, close and punitive style where the supervisor allows his subordinates little or no influence in the setting up of work procedures, while primarily concentrating on achieving task goals.

We approached the twenty-four TA project case studies in terms of these three categories of leadership style. While the project leaders were not all pure text-book examples of one or another of these styles, most could not be categorized without difficulty.

> FINDING 14: Projects with democratic/facilitating leaders produced the most integrated reports (N=10, average overall substantive integration equals 3.17), followed by authoritarian leaders (N=7, average overall substantive integration equals 2.14), followed by laissez-faire leaders (N=3, average overall substantive integration equals 1.93). [Analysis of variance yields $F=3.22$, $p=.065$. Statistical significance should be considered cautiously here as we are dealing with a population, not a sample. However, we are interested in generalizing beyond that population, but do not have a representative sample.]

Discussion: The laissez-faire management style typically consisted of the leader giving assignments to the team members and offering minimal supervision and coordination. In the final project phase the leader wove the output of the individual team members into the final report. This put a considerable burden on the leader. Moreover, because of the lack of direction throughout the project, chances that the work of the various team members would fit together and/or relate to the project were greatly diminished.

The authoritarian style followed a pattern of close control by the leader. In a number of instances, team members complained that the leader had overruled their judgment in their specialty. This, they felt, was less than professional treatment. There is a more serious implication here than hurt feelings, however. The range and depth of expertise required in a TA outstrips one individual's competence. Thus, unless he is able to accept the views of the experts on the team, the authoritarian runs the risk of substantive errors. It was also reported that occasionally authoritarian control restricted the amount of information a team member received about other parts of the study. This is counterproductive to integration.

The democratic/facilitating style of leadership found the leader typically acting as a "primus inter pares." While open discussion was encouraged and expertise within a team explicitly acknowledged, the leader took full responsibility for effecting closure as required. It appeared easier for those project leaders who had the respect of their team members to be democratic. Possession of stature within the organization appeared to make the leader's task easier. Having a solid intellectual grasp of at least the main features of each part of the overall task also appeared (from our interviews) to make the democratic leader role easier to play.

We used an ordinal index of management styles of increasing favorability to integration (laissez-faire, authoritarian, democratic/facilitating) which correlated significantly with a number of factors.

FINDING 15: Management style correlated with overall substantive integration (r_s=.51), systemic integration (r_s=.45), and depth of analysis of output (r_s=.42).

FINDING 16: Management style correlated positively with three measures of iteration: extent of average iteration of the parts of the assessment, extent of iteration of the whole assessment, and number of times the whole assessment was iterated (r_s from .63 to .76).

FINDING 17: Management style correlated positively with effectiveness of study bounding (r_s=.57).

FINDING 18: Management style correlated positively with an index of communication patterns favoring the all-channel mode over the hub and spokes mode (r_s=.40), and an index favoring continuing high interaction over an increasing interaction at the end of the project over decreasing team interaction at the end of the project, (r_s=.41).

Thus what emerges is the desirability of close interaction and sharing between the project leader and the team members in order to achieve product integration. This preference was reinforced in the experimental context where the democratic/facilitating style was generally adapted. The groups moved smoothly with the leader typically playing the role of guide and focuser, downplaying his personal contributions. With a change in leadership, the original leader became creatively active, while the new leader took on the other role--a splendid example of role reversal.

An interesting finding emerged when we considered the relationship between the disciplinary orientation of the project leader and the overall substantive integration of the project.

FINDING 19:

Disciplinary Group of Leader	Number of Leaders	Average Overall Substantive Integration of TA Report (1 to 5 Scale)
Social Scientists and Economists	3	4.0
Engineers	2	3.25
Natural Scientists	7	2.57
"Systems", Professional and Mixed Backgrounds	11	2.32

[Analysis of variance yields F=1.88, p=.17.]

Discussion: The extremely low numbers involved in each disciplinary grouping should certainly alert one against an uncritical acceptance of this finding. In particular, the ranking of those with systems or mixed backgrounds seems counterintuitive. However, an individual whose approach was systemic or "integrative," or who had indeed integrated more than one discipline in his own intellectual background, might not be as aware of disciplinary differences as an individual who was conscious of his own single discipline background and hence of those of others on the team. This latter individual would be confronted explicitly with the need to integrate the efforts of the team members. Because of the limited time frame and the downplaying of disciplinary expertise, we could observe no effects due to the discipline of the leader in the experimental situations.

4. Team Characteristics

Our case studies revealed the operation of several team characteristics.

FINDING 20: As in the case of the team leader's background, the percentage of team members with a "systems" or multidisciplinary background correlated negatively (r_s=-.46) with overall substantive integration.

Discussion: While the numbers involved here are still too small for confident extrapolation, this independent result could be taken as reinforcing the finding advanced above. Apparently here too, internalizing broad and multiple perspectives in a single individual does not lead to a sensitivity or skill in integrating among or between individuals.

FINDING 21: From the core teams we obtained the following results for overall substantive integration:

Number on Team	Number of Teams	Average Overall Substantive Integration (1 to 5 Scale)
1	2	1.00
2	1	2.00
3	3	3.50
4	4	2.63
5	7	2.92
6	5	2.40
8	1	4.50

[Analysis of variance yields F=1.63, p=.20.]

Discussion: This information plus discussions with TA participants leads us to favor a core team of from three to five individuals for effective integration. Such a team is large enough for effective division of labor and small enough for good communications. Larger teams may be possible with good leadership and effective group interaction. The 8-member core team achieved its success by constant attention to the problem of integration.

FINDING 22: In our case studies the selection of team participants on the basis of their being present and available in the performing organization, and their having the needed technical specialty dominated all other selection criteria that might be utilized.

FINDING 23: Our case studies yielded a clear perception that major changes in a project team, especially the principal investigator, during the course of the project could hamper significantly the quality of its integration. These changes typically led to the consumption of project resources without corresponding output. Indeed, there were negative correlations between the extent of changes on the project team and satisfactoriness of study bounding ($\rho = -.58$) and more weakly with the various measures of iteration ($\rho = -.32$ to $-.41$)

Discussion: We were able to develop no significant quantitative evidence regarding the team members' interdisciplinary interest and collaborative experience. Our initial observations indicated that this would favor integration. However, it could equally be observed that the professionalism of researchers is strong, and their adaptive capabilities sufficient, to overcome most problems of this sort. Likewise indications of selection on the basis of interpersonal skills, as opposed to selection on the basis of expertise, did not yield any useful information. Based on our interviews, selection of team participants on the basis of being present and available in the performing organization and having the needed speciality seemed to dominate other factors in selection. However in the experiments, interdisciplinary interest and experience of the participants was strongly perceived by us to be a significant factor in the effective conduct of the exercises. In addition, interdisciplinary skills far more than disciplinary expertise were used in the experiments. The lack of time for depth analysis downplayed expertise in that context.

In a number of the cases we examined, where the project had been disrupted by instability of the team, a fairly obvious remedy was applied with some success. The performing organization would assign new personnel to get the work done; and, if the resources were largely expended, would put in more of either their own resources or the NSF's. Such a remedy could -- and did in a least one case we observed -- mitigate the effects of team instability on integration.

Some general criteria for effective participation in TA teams come from Professor Samuel Estep of the University of Michigan Law School, who was a participant in one of the TAs in our sample (private communication, 1977). A participant in a TA, he said, should be intelligent in the culture of academic life. Common sense helps, and the participants should be open minded with intellectual curiosity. A stable ego can take attacks on one's ideas without interpreting them as personal attacks. One's own value assumptions can be questioned. Internal organization and self discipline are complemented by a hard-nosed result orientation. The would-be interdisciplinary participant must not be afraid to ask simple or stupid questions, never be frightened about terminology, or easily snowed. Being able to get along with other people, one should accept responsibility for mistakes and learn from them.

5. Motivations and Rewards

The observation that individuals who are motivated toward, and rewarded for doing, quality interdisciplinary work will be more likely to produce a quality output seems obvious and important.

FINDING 24: There is no direct significant correlation between the index of motivation described earlier and integration.

Discussion: One explanation for this finding is that most researchers are professionals who will find a way to carry out their task. In the experiments the small monetary rewards offered were far outweighed by interest in interdisciplinary research and research professionalism in the judgment of the experimenters. This professionalism was manifested by the groups' taking essentially no breaks, working through lunch, and invariably exceeding the period of the session. Particularly in CROs, multidisciplinary and interdisciplinary research are commonly performed. Here the rewards for doing TA successfully are the same as those for doing any other form of research successfully. In academia, on the other hand, the environment is usually hostile to interdisciplinary research. Team leaders and participants are aware of the characteristics of their organization and can take steps, if indeed any are possible in the particular environment, to mitigate the problems associated with interdisciplinary research. For example, a number of project reports have been published as jointly authored books. These include the studies of offshore oil and gas exploration (Kash et al., 1973) and air pollution due to automobiles (Grad et al., 1975). In addition, it may be possible to give team members the opportunity for individual recognition by the possibility of publishing discrete methodological or substantive contributions as journal articles or presenting them as conference papers.

6. Epistemological Distances

Fairly early in our interviews the generic problem of communication among the disciplines appeared as four specific epistemological gaps that commonly occurred in the TAs in our study. These epistemological problem areas are:

1. Relying solely on data in hand or on a validated theory for projecting beyond the present data versus speculating about future eventualities beyond that which is strictly permitted by the data or theory.

2. The development of social impact assessments -- how should/can such assessments be performed?

3. Relating economics to other disciplines and to other modes of analysis.

4. The use of techniques designed especially for TA or other studies of the future.

Findings relevant to these four epistemological problem areas were as follows:

FINDING 25: As regards the problem of data verses speculation, two patterns were noted in our case studies. One was the flat refusal to go beyond the data. The other was one of more willingness to speculate in areas where, it was believed, sound knowledge did not exist. It was often felt that there was no point in gathering data in cases such as social impact assessment when common sense, possibly coupled with some expert opinion, was perfectly adequate. Our case studies also indicated more willingness to speculate in areas where the individual doing the speculating was not an expert, than in those areas where he did possess expertise -- especially in the case of assessing social consequences. Consequently, the need to generate additional data to form a more adequate basis for speculation about the future became a matter of controversy.

FINDING 26: While it was universally perceived that social impact assessment was necessary in TA, no one claimed that there was a foolproof way of doing it, and no one was fully satisfied with the way it had been done. Some abandoned hope of anything like a systematic analysis, but, realizing that the area was extremely important to a TA, they turned to a common sense discussion of social impacts in ordinary language. Others turned to quasi-quantitative techniques which were developed to organize and analyze opinion, speculation, and other "soft" forms of information into output with the form and quantitative precision associated with "hard" methodology. In neither case was anything like complete satisfaction expressed in the research output.

Discussion: Some of the participants in our case studies claimed that social impact assessment could not be done or at least could not be done beyond the level of common sense, and then with very limited reliability. Social impact assessment was compared by one respondent to "dreaming." In part, such sentiments arose from an often expressed preference for "hard" engineering or scientific approaches. Social science was seen as "soft," and hence wishy-washy and undesirable. The social scientists we encountered were mainly data-oriented.

Seemingly more so than any other discipline involved, they wished to generate original data in the TA. Hence conflict arose in a number of instances between modeling the situation at various levels of sophistication, and empirical data gathering with a limited conceptual backing (for a treatment of the a priori and empirical styles of inquiry, see Churchman, 1971).

In a number of cases no senior social scientist was a member of the TA team. This was generally perceived by the other team members as a significant deficiency. When the TA team did include social scientists, sometimes they felt that the project team leader -- in these cases a physical scientist or an engineer by training -- was deprecating social science and its methodologies and treating the social scientist participant unprofessionally. In some cases the issue involved the question of whether the social scientists should conduct surveys of involved parties as input to the social impact assessment component of the TA. Rejection of these plans as being useless or irrelevant to the study signalled to the social scientist the deprecation of his or her discipline.

This problem did not exist in cases where a social scientist or policy analyst was the team leader, nor did it exist when the team leader allowed the social scientists to follow their methodological bent. Interestingly, physical scientists and engineers in general felt far more confident doing social impact assessments (such as they perceived could be done) than social scientists felt in considering future technologies.

FINDING 27: On a number of the TA projects we studied a combination of several factors involved in performing social impact assessments served to alienate the social science participants and cause friction on the project team leading to output fragmentation.

Discussion: One point which indicates a strong coupling between epistemological and social - psychological factors is the widespread perception of "pecking order" of prestige among the academic disciplines. Social scientists were perceived as being near the bottom of the "academic totem pole." (The second of our group experiments offered some confirmation of this perception). The social scientists are often viewed by natural scientists and engineers as offering little firm knowledge. Thus the results of the former are viewed as not as significant as those of the latter. In addition, since group consensus within the social science disciplines is not as strong as that within the physical sciences, more methodological uncertainty is expressed. These and other other factors mentioned above are, in combination, often sources of friction and fragmentation on TA projects.

FINDING 28: Economics stood out as a discipline with a jargon, methodological preoccupations and requirements, and a view of the world which frustrated many of the other TA participants.

Discussion: Everyone conceded that economics was an essential discipline for TA, since changes in technological systems invariably have economic consequences. While all disciplines have their own specialized terminology, problems with the economists' jargon -- and their difficulty in translating it into language intelligible to the non-economist -- stood out in their universality and perceived importance.

Beyond the problem of specialized terminology, our case studies revealed other substantial problems in interaction with economists. Some economists were wedded to building and using complex mathematical models which were perceived by the other participants as having little validity or utility. One project leader expressed the wish that his team's economist could find a middle ground between highly complex models and relatively trivial extrapolations. In addition, as input to their complex models, economists were often perceived as requiring data which are not only unavailable, but unobtainable. This combination of esoteric models and data demands led to frustration among other team members.

Another significant problem we encountered was the apparent inability of economists to extend their analysis from cost measured in money flows to cost associated with social and other factors. Some TA participants questioned the value of the economists' work, given their disregard of these broader considerations. More than most, the economists seemed to feel that their work was a self-sufficient reflection of reality, with little need for the analytical contributions of other disciplines.

There appears to be some tension here between these problems with economics (and also those with social impact assessments) and the earlier finding that project leaders from economics and the social sciences produced more integrated TAs than those from other disciplinary groupings. The resolution of this apparent tension may lie in the observations that "there are economists and then there are economists" or "there are social scientists and social scientists." Indeed one solution was to use surrogate economists, MBAs or systems analysts, to perform economic analysis. However, in the final analysis, these problems may possibly be overstated or exacerbated by the personnel selection procedures employed. Many economists are both able to communicate with non-economists and have interest in broader institutional and behavioral aspects of economics, as well as policy implications. Selection criteria such as these may be utilized, as well as the obvious criteria of professional competence and availability. The situation with social scientists is analogous. Here too one may look for an intellectually and methodologically broad individual who can be at home with individuals trained in the natural sciences and technology, and who is interested in policy.

The final set of epistemological problems uncovered by our studies involves the validity and utility of the collection of techniques for generating and processing information about the future. These techniques, which are also employed in future-oriented studies other than TAs, include Delphi surveys, cross-impact matrices, relevance trees, and so on (c.f. Hetman, 1973; Hencley and Yates, 1974). The avowed purpose of these devices is to make quantitative, precise, and systematic what is qualitative and imprecise.

FINDING 29: The most typical reponse of the participants in the TA projects we studied to the variety of techniques designed especially for TAs or other future oriented studies was to ignore them. The second most frequently found reaction was to use some of these techniques sparingly as devices for organizing thought. The least frequently found response was approbation of the techniques because they made the TA quantitative and precise.

Discussion: The majority, who simply ignored these techniques for generating and processing information about the future, felt that they simply recast extant information without adding anything significant. In fact, many felt that such recasting gives a false impression of precision to what remains imprecise. The second group of respondents occasionally used such devices as cross-impact matrices for the purpose of focusing further impact analysis. They would want to insist, however, that no claim be made that such "guesstimates" which went into filling the matrix have been therby transformed into anything more than that. Finally, the least common position found more than heuristic value in these future-oriented techniques. This seemed to accompany a methodological bias that being quantitative adds value to a study. Most TA performers, however, were completely unimpressed by that position.

Additionally, in order to better understand how the particular mix of disciplinary backgrounds on a TA team affected integration, we constructed two indices. One of these was a loose quantitative approximation, developed by our team, of the "distances" between the various disciplinary groupings based on our interpretation of interview results. This index is represented in Figure 3.

	1	2	3	4	5	6
1 Social Science	0	1	2	2	2	2
2 Economics		0	2	1	0	2
3 Natural Science			0	1	1	2
4 Engineering				0	0	2
5 Systems Professional Mixed					0	2
6 Law						0

Figure 3 - "Intellectual Distances" between Groups of Disciplines

The pairwise distances between core team members were summed and normalized to reflect the number of team members. The second index was the percentage of core team members with multidisciplinary, professional, or "systems" backgrounds. The analysis of these two indices (which are negatively correlated as expected, $r_s = -.70$) in conjunction with other measures yields some interesting and surprising results.

FINDING 30: The greater the intellectual distance among the core team members in our case studies, the more substantively integrated the study output. ($r_s = .50$).

FINDING 31: The lower the percentage of systems, mixed, and professional backgrounds of the core team members, the more substantively integrated the study output ($r_s = .46$).

Discussion: On common sense grounds, we had initially hypothesized just the opposite of these two findings. One explanation of this discrepancy may be that the existence of diversity means that there is a greater chance of awareness of the potential for fragmentation. Realizing the intellectual differences within the project group, the participant may take special care to overcome its counterproductive potential and thus achieve integration. Where such diversity is not present, or where many of the individuals have multidisciplinary backgrounds, the problem of fragmentation may be more effectively masked and the appearance given that all is coming together well. As we have noted earlier, the ability of certain individuals to interrelate a broad range of perspectives in their own work may not necessarily enhance the integration of various components of a group project.

These indices, epistemological distance within team and percentage of core team members with systems or mixed backgrounds, also correlate with satisfactoriness of bounding ($r_s = .42, .38$), and the three measures of iteration ($r_s = .38$

to .73, .30 to .63). They also correlate as above with the depth of analysis of project output (r_s = .62, .58).

Participants in out TA case studies were asked to discuss the significance of the epistemological gaps in their project and also the significance of attempts by the project team to integrate the output of their work.

FINDING 32: The significance of the epistemological gaps within their projects correlated with other project characteristics as follows:

1) With the extent of changes on the project team (r = .65)
2) With satisfactoriness of bounding (r_s = -.58)
3) With the index of management style (r_s = -.41)

FINDING 33: The significance of attempts to integrate the results of their projects correlated with other project characteristics as follows:

1) With overall substantive integration of the project reports (r_s = .42)
2) Negatively with the extent of changes on the project team (ρ = -.51)
3) With satisfactoriness of bounding (r_s = .61)
4) With the index of management style (r_s = .45)
5) With the index of communications patterns (see section below) at end of project favoring the all channel over the hub and spokes configuration (r_s = .47)

7. Value Divergences

The issue here concerns the extent to which the participants in a particular technology assessment had fundamentally divergent or dissimilar value orientations, and the implications of such differences for the TA process and/or product. No quantitatively significant evidence bearing on this issue emerged from our case studies. While we thus have no direct evidence at this point, the following line of reasoning and data suggest that the project participants in our case studies may have been sufficiently similar in their basic value orientations to preclude the emergence of this issue as a problem.

For the most part NSF-sponsored TAs are performed by individuals who are university trained, technically oriented, and reflective of a distinctively Western frame of mind. Rokeach (1973) has documented a ranking of 36 values about which members of this group are in substantial agreement. Personal values, especially those relating to the acquisition and organization of knowledge (epistemological issues), tend to cluster around a common core. Highlights of this convergence are: action should be legitimated by reasons, problem-solving involves analysis or the breaking down of a complex problem into manageable components, and quantification is highly prized. On the other hand, intuition is considered suspect and synthesis is considered unreliable, especially because of their lack of quantitative precision.

The implications of this cluster of values are, for the most part, straightforward and do not require elaboration. One should be highlighted however, since it involves a rather distinctive characteristic of the technology assessment enterprise. The professionalism of almost all the participants in our case studies meant that while strongly held social and political values were often involved in the subject of the assessment, the team members functioned as analysts rather than champions of the values being considered. In the one case study in which there was substantive public participation, the solar energy TA performed by A.D. Little, Inc. (see Arnstein, 1975), both the professional researchers and public representatives realized that, as groups, their interests in the study were different. The researchers were concerned with doing a piece of professional research, while the public participants saw the study in terms of their own interests and values. Needless to say, this is an example of a very basic value difference in a TA. In this particular project the matter was never resolved. No value clarification session was held in order to get at the roots of the basic differences involved. The research team completed the study from its perspective with some critique and input from the public interest panel. The split was never bridged.

In several other cases as well, significant value divergences arose in the course of the research which reflected differing veiws of the subject of the assessment. These differences occured within the research team itself and were discussed in team meetings. We found no common technique or procedure for getting the divergent value assumptions of the team members fully explored and resolved. Systematic procedures have been tried in situations relating to the management of organizations. Indeed we used values clarification in our second experiment of rank ordering disciplines. Such excercises and procedures may be well worthwhile for TA practitioners to consider, especially in an assessment involving values which are strongly held and about which there may be strong polarization.

8. Bounding

The bounding of a TA, that is, setting the limits and form the inquiry is to take, is a process which continues throughout the study. Many of our respondents noted the ongoing nature of the bounding process by indicating a range of time instead of a point during the project at which bounding took place. Armstrong and Harman (1977) suggested about 20% of the time for the study should be spent in information gathering activities leading to study bounding. While this time varies from study to study, it is clearly desirable for the main features of the work to be set sometime during the first half of the study. Other bounding decisions can then be made throughout the course of the study as required. Because unanticipated problems occur during the course of any research, the flexibility to modify study bounding and changes in expectation should be maintained.

FINDING 34: It is clear from the case studies that effective bounding is one of the central factors in effective integration. It correlates directly with integration and with the major variables affecting integration.

Discussion: Because of the ongoing nature of the bounding process and the variations between studies, the optimal time range for bounding will vary from study to study. In our case studies the most useful indicator of bounding was its satisfactoriness as judged by the study participants.

FINDING 35: The study participants' judgments of the satisfactoriness of bounding correlated with other characteristics of the projects as follows:

1) With early bounding of study limits ($r_s = .51$)
2) With early bounding of study form ($r_s = .58$)
3) With the product measures of overall substantive integration ($r_s = .43$)
4) With the product measures of systemic integration ($r_s = .47$)
5) With the product measures of depth of analysis ($r_s = .62$)
6) Negatively with increasing changes in project personnel ($\rho = -.58$)
7) Strongly with the three measures of iteration ($r_s = .64$ to $.83$)
8) With the index of communications patterns favoring all channel pattern over the hub and spokes ($r_s = .44$)
9) Negatively with the significance of the epistemological gaps ($r_s = -.58$)
10) Positively with significance of attempts to integrate ($r_s = .61$)
11) With the management index favoring democratic/facilitating style ($r_s = .57$)
12) With the normalized index of intellectual distance within the project as determined by the specialties of the team members ($r_s = .42$)
13) With the four measures of project enjoyment ($r = .61$ to $.73$)

Discussion: This evidence confirms the importance of satisfactory project bounding in determining the extent of integration. This is hardly surprising, but it is still a persuasive argument for paying careful attention to the bounding decisions in TA activities; the payoff is in the quality of TA integration.

9. Iteration

Iteration is the process of redoing as assessment one or more times. Iteration allows what was learned in the later phases of the research to affect the earlier phases, as well as allowing analysis in various areas of expertise -- which were initially discrete -- to affect one another substantively. In addition to this integrative function, iteration plays the additional role of smoothing and better organizing a final product for communication with the user. For all of its usefulness, however, iteration is time consuming and therefore costly. When a project gets behind schedule, as most of the studies we considered were, iteration is a prime candidate for elimination, as the study can be completed without it.

The extent to which the products in our case studies were iterated was evaluated by the participants using three measures: 1) extent of iteration of parts of the assessment, 2) extent of iteration of the whole assessment, and 3) number of times the whole assessment as iterated.

FINDING 36: As evaluated by the participants in the case study TAs, the 3 measures of iteration utilized were found to be strongly intercorrelated (ρ = .50 to .77; r_s = .45 to .77)

FINDING 37: The 3 measures of iteration correlated with other project characteristics as follows:

1) With the product measures of overall substantive integration (r_s = .50 to .56)
2) With systemic integration (r_s = .56 to .67)
3) With depth of analysis (r_s = .51 to .61)
4) With the index of management style (r_s = .63 to .76)
5) With index of intellectual distance (r_s = .38 to .73)
6) With 2 indices relating to communications patterns, closeness to all channels (r_s = .29 to .63) and high level of interaction throughout the project to interaction level rising at the end, to interaction level falling at the end (r_s = .54 to .59)

Discussion: Like bounding, iteration turns out in our case studies to be an extremely important factor in integration. It provides the opportunity for the integration of discrete analyses, as well as earlier and later project phases. Our data endorse Armstrong and Harman's concern (1977) for iteration as an essential part of TA study strategy.

10. Communication Patterns

The final variable to which we would call attention concerns the patterns of communications that may characterize a TA project. The actual communications patterns on a given project are strongly influenced by management decisions. The patterns may also vary from phase to phase as the project unfolds and as the character of team activity changes. In our analysis we considered two polar communication patterns: the all-channel (or any-channel) pattern, and the hub and spokes pattern, together with intermediate configurations (the two polar opposite patterns and a possible intermediate case are illustrated for a five member team in Figure 4). Pure examples of the polar cases are rarely found. Intermediate configurations are typical.

A. All-Channel (any channel) B. The Hub and Spokes

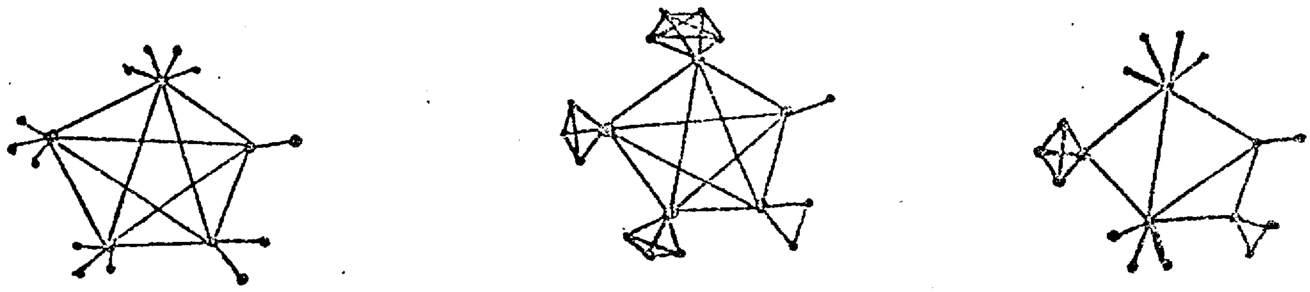
Figure 4 - Communication Patterns

In the classic literature on small groups, Bavelas (1950) and Guetzkow and Simon (1955) have found the hub and spokes to be the most effective arrangement for communicating simple factual information and performing simple tasks. As the complexity of the task increases, the all-channel configuration becomes more appropriate. The additional complexity of the all-channel pattern over the hub and spokes increases quickly as the number of participants increases. The maintenance of these additional links requires time and effort which would otherwise be expended as individual research effort. The tradeoffs involved are different in each situation. To maintain a core team of reasonably small size, support arrangements for core team members may be considered which will decrease the number of links when contrasted with a large all-channel system. Some possibilities are illustrated in Figure 5.

FINDING 38: True interdisciplinarity seems to require something more than the hub and spokes but the unwieldyness of the all-channel system with larger groups leads to complications as well. If an all-channel system is used, the strength of the channels should probably be unequal.

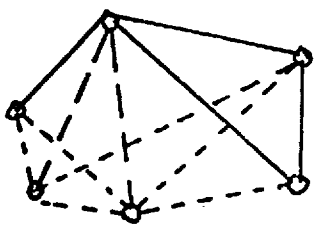
Discussion: Figure 6 shows the communication pattern drawn by the principal investigator of a successful TA. It is nearly an all-channel pattern, but with links of varying strengths.

Two indices were used to analyze the communications patterns in our case study TAs: 1) an index in which the all-channel pattern was favored over intermediate configurations, which, in turn, were favored over the hub and spokes pattern;



All-Channel with Wheels　　All-Channel with All-Channels　　Combination

Figure 5 - Possible Combination Communication Profiles for Project Groups



Strength of Channel

strong
intermediate
weak

Figure 6 - A Communication Profile in One Successful Study

2) an index of level of interaction in which high interaction throughout the life of the project was favored over interaction increasing to a high level by the end of the project over interaction which decreased over the life of the project. These two indices were correlated at the level of r_s=.48.

FINDING 39: The index of communication pattern types was found to correlate with other characteristics of the TA case studies as follows:
1) With satisfactoriness of bounding (r_s=.44)
2) With the three indicators of interaction (r_s=.29 to .62)
3) With the index of management style (r_s=.40)
4) With overall substantive integration (r_s=.45)
5) With systemic integration (r_s=.45)
6) With significance of attempts to integrate (r_s=.47)

FINDING 40: The index of interaction correlates with other characteristics of the case study projects as follows:
1) With satisfactoriness of bounding (r_s=.32)
2) With the three indicators of iteration (r_s=.51 to .65)
3) With the index of management style (r_s=.41)

In addition to the above analyses, we also determined (on the basis of drawings by practitioners we interviewed of the actual communication links on the projects) those of our case study projects which had a clearly dominant communication pattern. For these TAs the relationship between their type of communication patterns and their overall substantive integration was:

FINDING 41:

	Body of Project		Final Phase	
Type of Communication Pattern	Number of Studies	Average Overall Substantive Integration	Number of Studies	Average Overall Substantive Integration
All-channel	2	3.50	4	3.80
Intermediate	12	2.96	8	3.25
Hub/Spokes	7	2.29	9	1.92

[Analysis of variance yields $\underline{F}$=1.08, $\underline{p}$=.36 for the body of the project; $\underline{F}$=6.75, $\underline{p}$=.007 for the final phase.]

Discussion: These results confirm the claim that all-channel communication patterns are better for the conduct of TAs, especially in the final phase. In addition, we cannot help remarking on the uniformally negative reactions of the participants on projects where the hub and spokes pattern was the dominant communication mode. They felt that such an arrangement was unprofessional, since it did not allow the researchers an opportunity for interaction with their colleagues. They felt that this was essential to assure the possibility of using substantive results of other project participants as direct input to their own work.

The experimental groups clearly maintained an all-channel communication pattern throughout the exercise. However, some links were stronger than others. This constant give and take clearly strengthened the project. When, at the end, under time pressure, a hub and spokes pattern emerged, this was a major factor in the absence of integration in the group report.

11. A Causal Model of Factors Affecting Integration

Working from our initial influence diagram (Figure 2) and the correlations of specific indicators discussed above, we used multiple regression and factor analysis to aid in developing a simple causal model which would account for much of overall substantive integration by a few indicators. To perform this analysis we used a simple application of the technique of path analysis (Nie et al., 1975; 383-397). The technical details of our multiple regression and path analyses and our causal model are presented in Appendix F. We began with the initial hypothesized influence diagram and looked at areas where we had indicators with significant correlations. Using the initial correlations, we eliminated a number of areas, primarily boundary conditions and those where our data were not robust. In our final model we used six composite independent variables and a single dependent variable, overall substantive integration, INT. The independent variables are as follows:

LEAD reflects the leadership factor. It is an equally weighted composite of the leadership style index discussed above and the respondents' evaluation of the team leader's emphasis on integration. The Pearson correlation between these two variables is .14, which is not unreasonable since there is no strongly positive connection between these variables.

TEAM reflects various characteristics of the project team. It is a composite of core size, coded binary, with 3 to 5 preferable to any size, weighted twice; plus the respondents' evaluation of TA-like joint prior work by the team members; minus an indicator of the degree of changes on the project team during the life of the project. Not surprisingly, team size correlates strongly with neither of the indicators; for prior joint work and changes, $\rho = -.43$.

BOUND is an indicator of bounding. It is composed of indicators of early setting of limits and of form. Added to these two with a weight of two is an indicator of satisfactoriness of bounding.

COMM indicates the communications patterns and level of communication during the project. It is composed of the index of communication patterns, from wheel to all-channel, weighted at 7; plus 7 indices weighted at one. These are the relative level of interaction during proposal preparation, early phase, middle phase, latter phase, and final report writing, as well as the respondents' judgment as to frequency and importance of informal group meetings, and frequency of formal meetings.

ITER indicates extent of iteration of the research. It is composed of equally weighted indicators of the extent of iteration of the parts of the assessment, the extent of iteration of the whole assessment, and the number of times the whole TA was iterated. The intercorrelations here vary from $\rho = .50$ to $\rho = .77$.

EPIS deals with epistemological gaps on the project. It is composed of the equally weighted indices of disciplinary disparity of the project team as normalized for the number of team members, and the self rated significance of epistemological gaps. The correlation between these two is negative, $\rho = -.21$.

Comparing the influence diagram (including the indirect causal links, which were not shown) with the constructed variables described above, and making use of the intercorrelation matrix of the seven variables, we worked through a series of causal models. We refined progressively until we reached the model shown in Figure 7.

While this model has the limitations on its data described earlier, its causal links are plausible, and it accounts for half the observed variation. A brief discussion of the causal links and the discrepancies should help to clarify this.

The model omits boundary conditions on the project whose influence is diffuse and variables where we did not feel our indicators were satisfactory. LEAD played a stronger causal role in the final form of the model than we had anticipated in the beginning. The leader's style is a prime direct influence on a wide range of decisions. The leader has the last say on the number and composition of the core team and is a major factor in team cohesion. A number of respondents noted that the leader's style either kept up team cohesion or resulted in defections during the course of the project. Leader control over project personnel sets the boundary conditions for the communication pattern and level of interaction within the core team. Decisions affecting the bounds

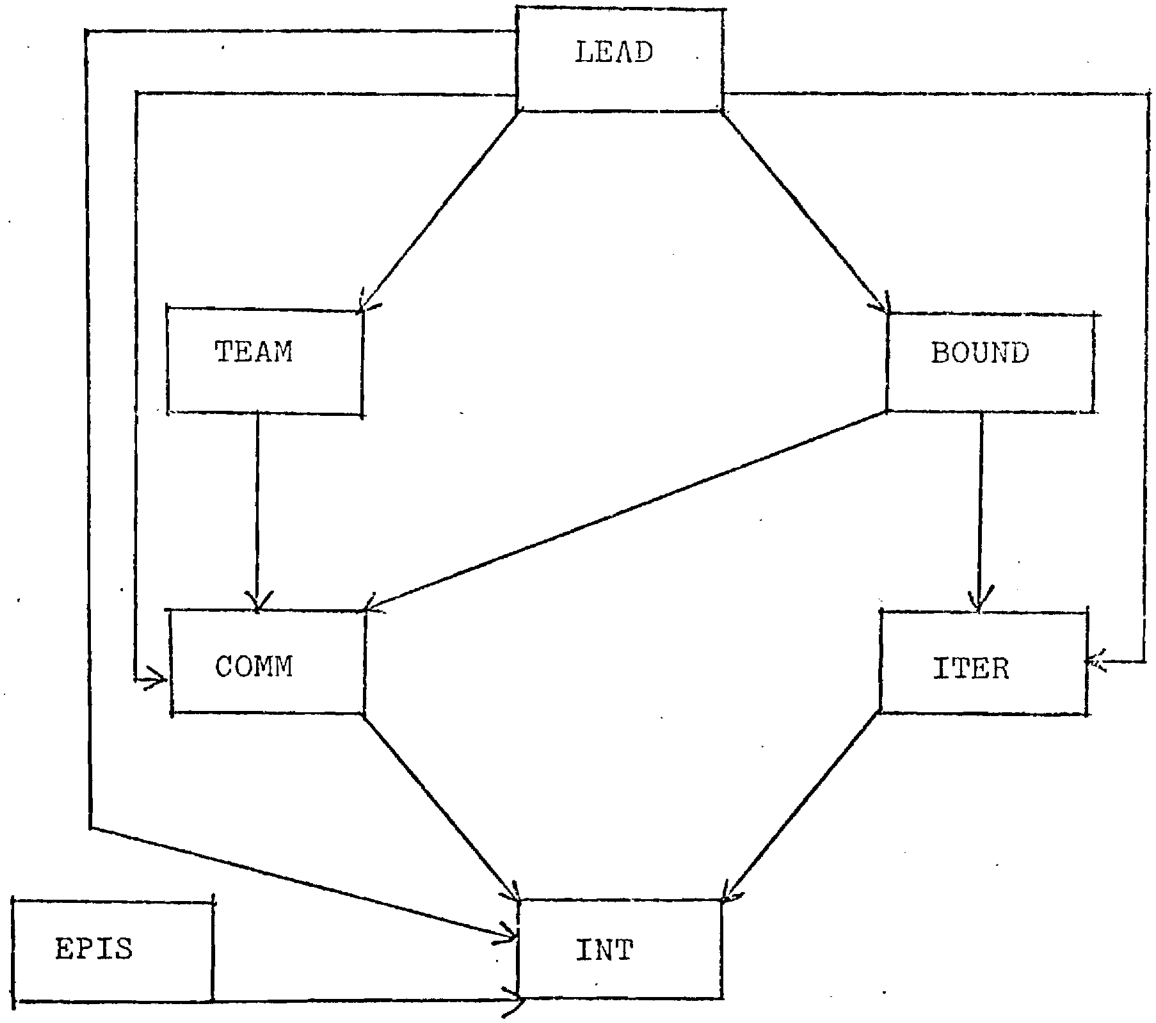


FIGURE 7 A CAUSAL MODEL FOR TA INTEGRATION

of the study and any provision for iteration belong ultimately to the leader, whose operating style and interest in integration are key influences. Direct influence on integration is connected with the leader's emphasis on integration.

The other variables did not have as many causal links as LEAD. TEAM's causal influence on COMM can be accounted for by number on core team as a determinant of communications pattern, and their joint prior experience as a determinant of intensity. Two of our three major discrepancies involve TEAM. We interpret the TEAM-BOUND link non-causally because the team characteristics do not operate causally to determine bounding. Likewise iteration procedures did not appear causally dependent on team characteristics. The link between TEAM and INT is seen as mediated through COMM. BOUND is seen as causally influencing ITER and COMM and, indirectly through them, INT. The final discrepancy is between COMM and ITER where no causal relation is indicated. Non-causal correlations between the pairs of variables where discrepancies exist may account for these. Appendix F presents the details of the discrepancies.

This causal model makes for a good starting point for further testing of the broad range of considerations affecting integration, as well as a general guide for procedure in a particular study. Without pinning great faith on the details, this picture could be used broadly to structure a study for more effective integration, or as a diagnostic guide in case of difficulties.

III. CONCLUDING OBSERVATIONS

In this section we offer specific guidance for developing strategies for integrating technology assessments. In so doing we will summarize some conclusions drawn earlier in the report, and apply some results to various types of TAs which may be of particular interest.

The type of integration desired in a TA is that proper to a truly broad interdisciplinary study where no substantive, overarching theoretical framework spans the disciplines involved. Thus more than editorial and conceptual/terminological integration is required, yet theoretical integration is unattainable. The forging of substantive internal links among disciplinary contributions is what is required. In addition to disciplines there is a separate dimension, parties-at-interest, which may form the basis of dividing--and integrating--a study. While our primary focus has been on division and integration by disciplines, both dimensions may be used as bases of integration. One can divide along either dimension and effect partial integration along the other. A well-integrated study would seem to involve interrelationships along both dimensions.

In order to forge these linkages it is desirable that the study meet certain conditions. We summarize our principal findings regarding these.

1. The project leader should have a democratic/facilitating style (making decisions jointly with the project team, being supportive of team members, and possessing effective control over project personnel and other resources). If this cannot be achieved, an authoritarian style is preferable to a laissez-faire style.
2. For the level of project effort considered in the study, a 3 to 5 member core team covering a broad range of disciplines relevant to the TA study is appropriate. Team stability (and especially that of the project leader) is desirable throughout the study.
3. Study bounding is an ongoing process. However, it is highly desirable to settle the main limits and form of the study early. Such bounding should be satisfactory to all team members.
4. Time and resources should be explicitly budgeted and used for iteration of the study components and the entire study.
5. The possibility of "all channel" communication within the core team should be insured. A high level of interaction among project personnel should be maintained especially during the project's final phases.

6. Significant epistemological gaps should be expected and recognized. The four most common specific gaps identified concerned social impact assessment, economics, data vs. speculation, and the use of TA techniques.
   A. Social impact assessment is central to a TA, but lacks the methodological development of areas such as economic and environmental analysis. The team should include a social scientist. That individual should take the lead in social impact assessment, recognizing that the collection of original data is quite likely here. The contribution of the social scientist should not be underrated because of the low prestige of the social science disciplines.
   B. The person performing economic analysis ought to be intellectually flexible, have policy interests, and be able to relate intellectually with non-economists.
   C. All team members should understand that TA is future-oriented and that they need to be willing to speculate about the future in the absence of definitive data.
   D. Specific techniques designed for TA are typically devices to structure and develop information without a base in substantive theory. Their use should be considered as part of the choice of framework as outlined below.
7. A strategy for integration can be developed by choosing some combination of the socio-cognitive frameworks--common group learning, modeling, negotiation among experts, and integration by leader. We discuss the utility of these in various TA situations: well-defined subject/ill-defined subject, broad range of coverage/narrow range of coverage, technology emphasis/policy emphasis, and less than 2 person years of effort/2-6 person years of effort (corresponding to the studies in our sample)/greater than 6 person years of effort.
   A. Common group learning can be used for both well-defined and ill-defined subjects. However, the close group effort brings a variety of perspectives which may be useful in giving specificity to an area. This technique can cover various ranges of study scope. However, because of the requirement that each individual become an expert on the whole project, an extremely broad study would

normally have to be dealt with at a low level of depth. Because of the problem of technical mastery, common group learning is more appropriate for a policy oriented study than an assessment with a strong technological orientation. Common group learning appears more appropriate for studies up to a 6 person year range than for studies which are a half or whole order of magnitude larger. The complexity of the larger studies would seem to favor a division of labor, possibly hierarchical, in which the integrative core group contains representatives from various task areas. In this case, the members of the core group would not be expert in all parts of the study.

B. Modeling requires a well-defined subject matter. It cannot readily accommodate a broad ranging study which includes qualitative considerations to a significant extent. Models typically deal with technical considerations and economic impacts. Nor does modeling deal as well with a policy emphasis as it does with a technological emphasis. Modeling is appropriate for any size of effort.

C. Negotiation among experts can handle either a well defined or ill defined subject matter. However, it is stronger where some definition exists, as expertise can be more readily brought to bear in a structured situation. Negotiation can deal with a wide ranging study, as the centralizing constraints of common group learning and modeling are absent. Negotiation can be used either for a technology or policy emphasis. However, the broadest and most integrated study would probably result from the participation by all team members in policy analysis. The degree of division of labor used in negotiation is probably excessive for a very small study. Likewise, a very large study would probably require a hierarchial organization analogous to that described under common group learning.

D. Integration by leader appears most effective for relatively narrow studies at any level of definition with either a technology or a policy emphasis. Such an arrangement works best in small studies of between one and two person-years where a single investigator works with a group of consultants who use very little time. The small scale TA on the videophone by Dickson (1973) is illustrative of such a study.

Finally, we consider the question of what further research into interdisciplinary integration is appropriate. We recommend two sorts of studies. One is a series of experimental exercises in integration by negotiation among disciplinary perspectives. For example, cost benefit analysis and social impact analyses of a particular technology could be integrated by interaction among two professionals, and the process chronicled. Another example is integrating policy considerations arising from various perspectives. The results and techniques developed and used in the process might be transferable to other analogous situations.

A second sort of study is a comparison among generic approaches to integration. For example, three assessments of the same technology could be conducted under the primary modes of common group learning, modeling, and negotiation. Suitable controls would make other aspects of the studies comparable.

The research reported herein should serve as a guide to actual practice in TA, and to further research in the methodology necessary for handling the enormous complexity inherent in the performance and evaluation of every assessment.

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APPENDIX A
GEORGIA TECH TECHNOLOGY ASSESSMENT PROJECT
PHASE II INTERVIEW GUIDE

Introduction:

--short answer questions first

--come back to explore a few points in an open-ended fashion

--discuss open-ended questions

--confidential

Interviewer:______________________ Date:______________

Interviewee:______________________ Location:______________

Technology Assessment of:______________________________

1. What is the functional nature of the immediate organization performing the TA?

   University: Department
   Program/Institute

   Contract Research Organization: Division
   Other

   (Discuss as necessary)

2. In our interviews to date with TA participants, we have encountered different team arrangements. These might be classified in terms of the number of people playing central roles in the study, ranging from one person on up. Could you identify a "core team" in your TA? Yes ___ No ___
   (Discuss as necessary)

3. Whom would you identify as the core team members? and what were their backgrounds?

PERSON	BACKGROUND	LOCATION

4. Were there any changes in the core team membership during the course of the project? __________

What were they?

5. Besides the core team members, about how many other people from your organization participated significantly over the course of the project? _____

Where were they physically located relating to the core team?

What were their roles on the project?

6. What subcontractors or major consultants were used: (Location?)

What was their role on the project?

On a number of the following items we will ask for your opinion on 7-point scales

How would you rate the experience with each on a scale from 1 = unsuccessful to 7 = totally successful?

List Subcontractor(s) and Consultants	Rating (1-7)
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________
______________________________	__________

7. How did your organization's structure affect performance of the technology assessment?

Severely Impeded 1 2 3 4 5 6 7 Greatly Facilitated

Please write in your responses, as indicated. For the items with 7-point scales, please circle the number that best reflects your opinion.

8. To what extent were core team participants selected for:

	Not a criterion — Most important
Expertise	1 2 3 4 5 6 7
Interpersonal Skills	1 2 3 4 5 6 7

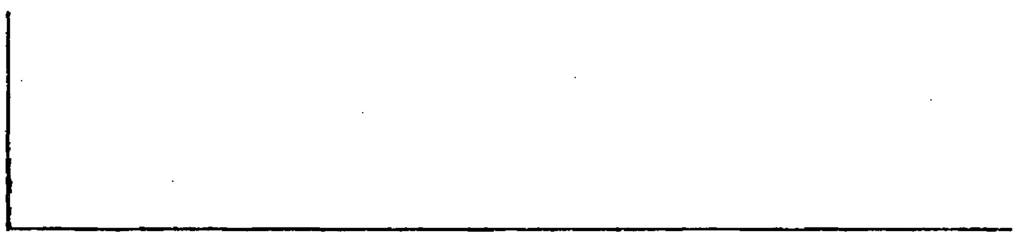
9. To what extent had the core team members worked together previously on a technology assessment or interdisciplinary research similar to technology assessment?

Not at all 1 2 3 4 5 6 7 Most of the team had worked together extensively

Describe

10. Could you profile the amount of core team interaction over the time course of the project below?

Meeting hours/week

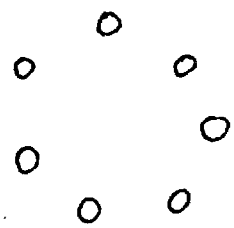


Proposal preparation — Problem definition — Impacts analysis — Policy analysis — Final Report

chronological time

-Meeting frequency
-Who present
-Character

11. Could you illustrate the prominent communication flow linkages that developed among the core team members below? (Show initials) Please indicate the stronger linkages with *'s.



(Use this as a stimulus to discuss epistemological and value barriers)

12. Did you feel that formal project team meeting improved the quality of the project output?

Not at all 1 2 3 4 5 6 7 Highly significant improvement

Did you enjoy the project meetings?

Not at all 1 2 3 4 5 6 7 Very much

13. Concerning the nature of the relationship between the project leader and the team members--would you characterize the project leader as:

--deciding the project objectives 1 2 3 4 5 6 7 depending largely on the group to set project objectives

--deciding how to perform the research tasks 1 2 3 4 5 6 7 depending largely on the group to set project objecti\

--lacking effective control over personnel (i.e., capability to get them to do what the leader wants) 1 2 3 4 5 6 7 having effective control over personnel

--non-supportive 1 2 3 4 5 6 7 supportive

14. --Could you rank the three most important personal incentives for

(a) Your Participation	(b) Participation of Project Leader (if you are a team member) or Team Members (if you are the project leader)	
________	________	new contracts/grants
________	________	"sold time"
________	________	publication--disciplinary
________	________	publication--interdisciplinary
________	________	interest in technology assessment/ interdisciplinary research
________	________	interest in the topic of assessment
________	________	learning experience
________	________	professional "quality" work
________	________	job rewards (financial reward; retention, promotion)
________	________	other (specify)

15. Turning specifically to integration (by integration we mean that the impacts and policy options analyzed in every domain of inquiry were used as substantive input into the analyses in every other domain).

What was the degree of relative emphasis on quality of component analyses versus integration of component analyses by ...

--sponsor or monitor

quality of
component analyses 1 2 3 4 5 6 7 integration of component analyses

--project leader

quality of
component analyses 1 2 3 4 5 6 7 integration of component analyses

--team members

quality of
component analyses 1 2 3 4 5 6 7 integration of component analyses

16. "Bounding" the assessment project (i.e. specifying the limits and form of the study) is often identified as an important step in a technology assessment.

--At what stage of the technology assessment would you consider that the following were determined:

Limits of the study (i.e. what was considered and what was left out)

never 1 2 3 4 5 6 7 at the beginning of the project

Form of the study (i.e. the use of various methods and techniques(such as analysis or trend extrapolation) and the depth of analysis undertaken.)

never 1 2 3 4 5 6 7 at the beginning of the project

--How satisfactory was the bounding in enabling the team to accomplish a viable study?

Unsatisfactory 1 2 3 4 5 6 7 totally satisfactory

17. Did the team develop and use any unifying substantive model in the assessment?

none 1 2 3 4 5 6 7 used a common model extensively

18. How extensively were parts of the assessment iterated on the average (that is, redone after critique)?

not at all 1 2 3 4 5 6 7 exhaustively

--How extensively was the whole assessment iterated?

not at all 1 2 3 4 5 6 7 exhaustively

--How many times was the whole assessment iterated?

19. How much did you enjoy

The project	not at all	1 2 3 4 5 6 7	very much
The project meetings	not at all	1 2 3 4 5 6 7	very much
Informal communication among the project team	not at all	1 2 3 4 5 6 7	very much
Performing your component of the research	not at all	1 2 3 4 5 6 7	very much

Open Ended Section

Follow up specific points raised earlier in interview.

Ask about any tensions between the project group and the larger organization.

On the project did you notice any problems in communication among people of different disciplinary backgrounds or any problems arising because participants had differnet ways of seeing the world? If yes ....

What were the nature of these problems? Get a detailed description.

What were the specific factors in these problems? e.g. data, theory, models, concepts, rules for developing knowledge, what the problem was, what was an adequate solution to the problem.

How, if at all, did they attempt to solve the problem? Get explicit information. Describe the process of resolution?

Group learning? ___ Overarching model? ___ Negotiation? ___ Other? ___

What were the final results? How were they reflected in the project output?

N.B. four identified problems areas were social impact assessment, economics, data v.s. speculation, TA techniques.

Did you observe any cases where any social/political/economic values influenced the TA or were injected into it by participants, consultants, subs, sponsor, etc? If so, what values, by whom and at what point in the study? Were these values contrary to any values implicit in the TA? What were they?

Describe any value divergences in the study and attempts at resolution in detail...?

What were the results and how were they reflected in project output?

Same as above except for methodological values...

N.B. cross disciplinary communication also involves methodological values... be redundant rather than omit.

What differences do you see this TA making to the world? (Use this to get macro views of TA, technology, and man.)

What kind of people are the most effective participants in TAs? e.g. How do they relate to other people? Is their range of knowledge broad or narrow? Are they methodologically rigorous, flexible, or loose?

APPENDIX B
SCALES USED TO RATE TYPES OF THE INTEGRATION, COMPREHENSIVENESS, AND DEPTH OF ANALYSIS OF TA PRODUCTS

Integration: Editorial

5 Hi - The report is well organized with clear and adequate introduction, transitions between parts, and conclusion.
4 Med-Hi - The report is organized coherently with introduction, transitions, and conclusion.
3 Med - The report is organized and editorially linked.
2 Med-Lo - The report consists of parts with very limited editorial linkages.
1 Lo - The report consists of uninterpreted pieces.

Integration: Conceptual/Terminological

5 Hi - All terms representing variables are used consistently, the same set of terms is used throughout the study.
4 Med-Hi - All terms are used consistently; terms are generally used throughout the study.
3 Med - There is at most a minimum of inconsistency; terms are sometimes used in isolation.
2 Med-Lo - There is a limited amount of inconsistency. Terms are often isolated.
1 Lo - Terms are sometimes used inconsistently and in isolation.

Integration: Systemic

5 Hi - The variables are contained in a well articulated model. Their relationships are made clear throughout the study.
4 Med-Hi There is a well articulated model which relates many of the variables.
3 Med - There is an articulated model which relates many of the variables.
2 Med-Lo - The variables are related weakly through a partially articulated model.
1 Lo - The study lacks any model or systemic view to relate the variables.

Overall Substantive Integration: a judgement made on a scale of 1 to 5 after completion of the other integration measures.

Comprehensiveness

5 Hi - Cannot identify any significant variables omitted.
4 Med-Hi - A single significant variable or a narrow range of variables is omitted.
3 Med - A few significant variables are omitted.
2 Med-Lo - Many significant variables are omitted.
1 Lo - Report concentrates on a single variable or a very narrow range of variables.

Depth of Analysis

5 Hi - The variables are articulated in detail; the relationships among them are well articulated and supported in detail using sound reasons and data, quantified where possible.
4 Med-Hi - The variables are articulated in some detail; their relationships are articulated and generally adequately supported.
3 Med - The variables are articulated; their relationships are generally articulated with some support being offered.

2 Med-Lo - The variables are articulated in a limited way; their relationships are not fully explored and weakly supported.
1 Lo - The variables and the relationships among them are presented superficially or ignored.

APPENDIX C

FORM FOR RATING TYPES OF INTEGRATION, COMPREHENSIVENESS AND DEPTH OF ANALYSIS OF TA PRODUCTS

Evaluator ______________________ **Date** ______________________

TA ______________________ **Status of Document** ______________________

	C	D	Ie	Ic	Is
Technology Description & Forecast					
Description & Forecast of That Part of Society Which Impacts the Technology	CA CM				
Context					
Environmental Impacts					
Political Impacts					
Institutional Impacts					
Social Impacts					
Technological Impacts (focus on Innovation)					
Legal Impacts					
Economic Impacts					
Impacts					

	C	D	Ie	Ic	Is
Environmental Policies					
Institutional Policies					
Social Policies					
Technological Policies (focus on Innovation)					
Economic Policies					
Policies					
Report					

Comments:

APPENDIX D

THE SMALL GROUP EXPERIMENTS

I. THE FIRST EXPERIMENT

A. Introduction

The research design of the first experiment was a factorial in which the order of problem to be "solved", instructional mode adopted for seeking a solution, and team leader would vary by session. Two teams would meet separately for three four-hour sessions (although session dates might span several weeks)--an admittedly crude approximation of team meetings in a real TA project. The number of participants and disciplinary composition of each team would reflect that most often observed, namely physical scientist, economist, social scientist (not an economist), "systems" person, and engineer or "systems" person.

With one exception of prior contact, the participants' teammates were all strangers who were professional researchers, i.e., faculty members, full-time researchers, or advanced graduate students from Georgia Tech's academic and contract research units, Georgia State, or Emory universities. (Wherever possible, each received remuneration, as consultants, for their time.) Because factors other than discipline, particularly one's "cognitive style" or epistemological views, have been shown (for a review, see Mitroff, 1974) to affect how one approaches a scientific problem, we attempted to gauge participants' variation on this intellectual dimension. During a brief informal interview, general biographical and educational data were secured. Then the participant's team research experience, functional roles played, collaborative writing patterns, preference for macro- vs micro-scopic problems, concern for theory, data, modeling, etc., avowed or implied penchant for interaction, leadership capabilities, and dominant personality characteristics were noted.

The problems presented to the two teams were typical micro assessments (Rossini et al., 1976) covering a range of disciplinary interests. The physical science assessment concerned decentralized solar energy; the biological, the clivis multrum, a waste disposal system; the social, the impacts of adopting an alternative work schedule, specifically, the four-day work week. The instructions as to which socio-cognitive framework should be used to do the assessment was varied from session to session. Common group learning is the lowest common denominator or compromise approach for guiding a group's effort; modeling requires representing (e.g., graphically) real-world relationships bearing on the problem to produce anticipated outputs (solutions); and negotiation among experts divides the problem by area of expertise and interest, followed by discussion of the expert analyses with the goal of linking them internally. Common to the instruction for all sessions were the suggestions (1) to bound the problem and identify the parties-at-interest, and (2) to iterate or repeat the process of individual and group analysis to achieve not only coherence but appropriate coverage of the policy options. The addendum contains the instructions that were distributed.

Each group was required to submit at the end of each session two documents: a substantive report including analyses and recommendations of actions to take regarding the problem, and a short methodological note on appropriate procedures (for the benefit of subsequent teams confronted by the very same TA problem and mode of operation). In these ways we sought to elicit both technical and personal reflections on the TA, the group experience, and one's own role as participant. Such reflections reveal an awareness of one's biases and perceptions, lending a subjective perspective to the group dynamics we observed.[1] The group reports plus our own observations were intended to generate additional hypotheses about group processes in TA (such as communication patterns, division of labor, value conflicts, and disciplinary flexibility), as well as provide independent sources of data on trends yielded by analysis of the 24 TA projects. We shall now consider the problem-solving sessions themselves, recount what occurred, and offer an interpretation of the proceedings.

B. The Experimental Sessions

The introduction of micro TA problems to a group of "scientific strangers" may appear to be an unorthodox experimental stimulus for eliciting social and intellectual processes which characterize team research. We imposed these conditions in the hope that over a three-session twelve-hour period of intense interaction a sampling of group dynamics would emerge. As in any experimental situation where independent variables are readily manipulated in an artificial environment, however, our design sacrifices external validity; we stake no claims for the generalizability of our findings. At the same time, we express confidence in the internal validity of the findings. "Microcosm effects" notwithstanding, the experiments succeeded in fostering and maintaining the participants interest.

Subject to institutional and experimental constraints of compressed time and no choice in the problems for study, the participants came to invest considerable ego in the problems and the particular roles they played in forging proposed solutions. Of course, one could argue that this ego investment did not rival the commitments one develops when PI status on a federal grant is involved, but commitment was certainly exhibited. For instance, the two groups routinely worked through lunch--nibbling while talking about the problem at hand--and exceeded the four-hour "limit" by a minimum of 30 minutes each session. Several remarks indicated that the sessions were more a technical challenge than an academic exercise and demonstrated time and again that when a professional scientist is confronted with a problem which requires some expertise he or she possesses, the scientist feels compelled to enter the dialogue, and contribute to the proceedings. This is what graduate training purported instills in the budding scientist--"creative tensions" (Pelz, 1967; Kuhn, 1963) or a responsiveness to what Mulkay (1972) calls "cognitive and technical norms."

In the summary that follows, those behaviors which we observed repeatedly, i.e., across groups and sessions, are highlighted. We believe that these behaviors illuminate the processes and structures which multidisciplinary research teams evolve to facilitate their mission, cope with their diversity, and to sustain their intellectual integrity.

The order of presentation of each TA problem, the instructional mode, and the discipline of each session leader for the two experimental teams (A and B) are presented in Table D-1. For example, the first cell entry shows that team A worked on alternative work schedules under the leadership of a systems person and with a common group learning approach in its first session. Rather than dwell on row and column comparisons, however, we prefer to review the team profiles generated by the design (Table D-2).

Assembled primarily according to disciplinary background and current professional identification, the teams were remarkably similar with respect to background characteristics: young, socially sensitive, and professing a macro theoretical approach to research. Greatest variance existed on experience with team research where the four systems people and the sociologist on team A excelled. Indeed, the success of team A relative to team B can be traced in part to the familiarity and comfort of the former with the team concept and the requisite compromise (i.e., consensus) solutions that the experiments demanded.

The most salient in-session characteristics differentiating the teams' performan are reflected in items 8 and 12 which set a definite tone for the work encounters. Regardless of instructional mode, A's ability to bound each problem swiftly established a strategy for further discussion; B's lack of experience delayed this initial closure. On both teams, however, the interactional styles of one's co-workers were recognized within the first hour of the first session and adjustments were made thereafter.

Table D-1

TA Problems and Instructions
Presented to Two Experimental Teams (A and B)
by Team (T), Session (S), and Discipline of Session Leader (L)

Instructions / Problem	Common Group Learning			Modeling			Negotiation		
	T	S	L	T	S	L	T	S	L
Work	A	1	Systems				B	1	Systems
Civis				A	3	Social Scientist			
				B	2	Systems			
Solar	B	3	Social Scientist				A	2	Economist

Table D-2

Background and In-Sessi... TA
Team Profiles

Background Characteristics	Team A	Team B
1. Disciplinary composition	physicist, economist, sociologist, systems (2)	physicist, economist, anthropologist systems (2)
2. Age (median)	32	30
3. Fraction with experience in team research	3/5	2/5
4. Social style (median) (1 = instrumental to 7 = socio-emotional; 1 = lo interaction to 7 = hi interaction)	6:6	5:5
5. Cognitive style (median) (1 = macro to 7 = micro; 1 = theory to 7 = data)	3:2	2:2
In-Session Characteristics		
6. Communication patterns	open, receptive reinforcing	open, indulgence due part to insecurity
7. Division of labor	mechanical, not based on expertise	mechanical, not based on expertise
8. Time taken to bound problem/reach preliminary consensus (median minutes)	40/80	75/190
9. Leader role style (authoritarian, laissez-faire, democratic)	democratic	democratic/laissez-fa
10. Degree of attitudinal/substantive conflict	almost none	almost none
11. Degree of reliance on individual expertise	only under "negotiation" condition	strength in togethern prevails
12. Degree of interactional learning	no ego problems; adjusted quickly, knew style and preference before end of session one	one two-person subgro emerged in session th
13. Success in following the instructions	criticized as ambiguous; had difficulty with "modeling"	difficulty with "negotiation"; actively resisted instructions t separate

Individuals consciously restrained their disciplinary biases, jargon, and even analytical preferences from "carrying the day." Suggestions were gently made, but deference to minority opinions was continually enforced in an apparent effort to build a fragile consensus. The absence of strong egos was neutralized perhaps by the imposition of a "revolving leader." Each group exhibited a disdain for the documentation provided on each problem (in the form of research proposals, reprints, newspaper articles, etc.)--one team member typically volunteered to peruse the material and report potentially useful information; brainstorming was the preferred activity. This seat-of-the-pants approach is well-suited for the production of highly-truncated recommendations derived from abbreviated discussion and analysis. This approach would seem more appropriate, under CGL, however, than the other modes of operation. Team B's insecurity about their respective roles in a group effort led to resistance to negotiation and precipitated intervention by the experimenter--a reminder that the rules must be followed. Not surprisingly, each team practiced democracy[2] as manifested by very attentive and reinforcing all-channel communications. Leaders functioned as recording secretaries and were insistent only about pacing the session, permitting short digressions (e.g., "What kind of model should we construct?), [3]and attending to the mechanics of completing the two written reports.

While no disciplinary differences were detected in effecting leadership, the incumbent would typically play the role of a coordinator and organizer at the expense of making creative contributions. At subsequent sessions with new leaders, the former leader would resume contributing actively to the group discussion--a classic case of role reversal. Social scientists did articulate the desire for data and concern for appending supporting documentation, at least in the form of bibliographic references, to the substantive reports. The reports per se were lucid and innovative in detail. They often contained predictions of higher-order impacts of the proposed TA. These reports also questioned the utility of the TA, its feasibility and costs in human terms.[4]

In all, a congenial work climate was created by the self-proclaimed "nonexperts" who dedicated themselves to the task: they were determined to do a creditable job with good humor. Consequently, respect was accorded all and decisions regarding strategy became a group activity. Indeed, when the teams divided labor under the negotiation condition, exchanging and meshing views into a coherent group product was difficult; strength resided, as the sessions conducted under the other instructional conditions illustrated, in their total number.[5]

II. THE SECOND EXPERIMENT

A. Introduction

Reflecting on the desing of the first experiment (e.g., what variables had we successfully isolated? What had eluded us?), we decided to conduct a second experimen somewhat complementary in scope and focus to the first.[6] Since our pool of scientist was not exhausted, we selected four (who had not participated earlier) for Team C, agreed to a session that would last 2 instead of 4-5 hours long, and chose a task that would bring differences in value assumptions and perceptions to the fore.

The single session with team C was led by an out-of-town colleague/management consultant, Ian Mitroff. The session was devoted to an exercise he calls "rank-ordering of the sciences" designed to elicit debate of the relative stature of academic disciplines which, in the area of social impact assessment, had been shown to affect team performance.

The team members were instructed to rank ten disciplines from 1 to 10 according to the criterion "intellectual stature." The term was deliberately undefined to allow each member to attach his values and meaning to it. To ensure that a rationale would be formulated, the second half of the exercise called for selection of a different criterion which would justify an inversion of the first rank ordering based on intellectual stature.

After completion of the individual rankings, the team would then discuss their respective rationales and decide on a group rank-order, according to at least one of the two criteria. The working hypothesis for the session stipulated that the airing of value differences as a group is vital if the members of multidisciplinary research teams are to communicate effectively and produce a coherent solution or recommendation on the research question which led to their assembly. That such differences consist of misunderstanding and ignorance about other disciplinary approaches, methods, etc., is viewed as a barrier to group process and therefore, to the utility and quality of the group research product. Because TAs are performed by such multidisciplinary teams, mechanisms which liberate values and facilitate trust, interaction, and communication, are sorely needed. It was to this end that the ranking exercise was designed. As the following description attests, the exercise also refined our monitoring of the group processes we initially sought to study.

B. The Session With Team C

The session was scheduled to proceed as follows: introduction (5 minutes), individual ranking (20), group discussion (40), debriefing (among the 4 team members, the session leader, and 3 observers for 45 minutes). The debriefing permits the leader to "intervene" and underscore the value implications of the participants' statements; it also allows participants to clarify their feelings about the interaction in which they had just engaged as well as to elaborate on the substantive issues which the exercise had raised.

The team was composed of four male faculty members, two senior and two junior in title and age. The senior participants represented chemistry and electrical engineering, the junior participants economics and political science.[7] The senior group members also knew one another prior to the session (though each had consented, as in teams A and B, to participate without knowledge of the other's consent).

Within 20 minutes, the individual rankings were completed and the group began to banter about the exercise. The discussion quickly turned to the bases for the first ranking, i.e., the interpretation of intellectual stature, as a way to achieve group consensus on that ranking. Several bases were mentioned; foremost among them were abstraction, rigor, predictive power, degree of mathematicization, and distinction as marked by awarding of Nobel prizes. After 10 minutes, the chemist (C) suggested that the ranks assigned to each science be added to produce a composite sum that would reveal a preliminary group ranking and indicate divergences in opinion that would require additional discussion.

During the next half hour, two patterns emerged: first, C became the dominant member of the group. He was the most assertive and task-oriented, but sensing his leadership position, also injected the most levity and "small talk" into the conversation. He clearly wanted his views to prevail, but not at the expense of alienating the other team members. In conventional terms, he sought to be an expressive socio-emotional leader, as well as an instrumental one. He would rather convince and convert than overpower. This approach (strategy?) had a catalytic effect, prompting the others to vocalize their concerns and misgivings, and in the process, their values and epistemologies.

The economist (EC) acted as foil to C. EC questioned the equation of stature with quantification ("It may be invalid or unfair—social sciences and psychiatry study living things."). C and EC thus became the focal points of the discussion, raising for examination the epistemological differences which we hypothesized to be present. Discussion centered on the math-physics-chemistry cluster versus the others. Electrical engineering was seen as an anomaly, not readily assigned to either the natural or the social sciences cluster. The EE member of the group offered information to reduce ignorance, but did little to persuade the group about EE's relative standing. The political scientist (PS) said that he suspected that "similar mechanisms" underlay the first ranking which would gain precision if the second ranking were discussed. Interestingly, "usefulness to man" or "public utility" was the genre of the second criterion. The exception was EC's "lack of mathematical modeling," an essentially negative criterion. C eventually adopted this criterion as his own since it allowed for a more complete inversion of his first ranking (he had placed physics and chemistry at the top of both of his rankings). EC persisted, asked the group to "be intellectually honest" and "cluster, not order" the sciences on the intellectual stature criterion. The group was most receptive to this compromis and agreed on three clusters: I. physics, chemistry, math; II. economics, biology, E III. anthropology, political science, psychology, psychiatry. Relief over this solution was evident. The group even expressed satisfaction with an inversion of the clusters to fulfill the second ranking assignment. Probably due to the focused nature of the problem, Team C had adopted a negotiation mode and worked more comfortably within it than either Team A or B.

C. Debriefing and Interpretation

The debriefing was conducted by the leader-consultant (L-C) who explained that the feedback was intended to sensitize the group to value assumptions and behaviors that can impede problem-solving. His discussion was offered to facilitate awareness of one's own and other's performance and to portray the exercise as a learning experience with implications for future tasks and team situations. Above all, the debriefing served to illuminate the gap between impressions the members projected and those which they thought were being communicated.

L-C began by discussing the virtues of "doing of vs. planning for" the task. Adopting and adhering to "decision rules" is organizationally sound if such rules do not stifle the expression of opinions, especially creative or offbeat ("you used a social process--agreement--to get an addition rule"). The communication structure evolved by the group will undoubtedly involve "gatekeeping" (though presently the structure was of the democratic, all-channel variety). A critical condition is a climate that is supportive as well as evaluative, receptive to deviant points of view. As for the criterion "intellectual stature", L-C noted that it has an arrogant and pejorative connotation, that scientists are trained to think in terms of scientifi method and perceive disciplines as more or less precise or "hard". Why isn't intellectual stature interpreted as "useful to man"? Likewise, was the second criterion selected a positive or negative one? How imaginative was it? What was the tenor of the discussion which ensued after the first ranking?

The exercise is intended to develop mutual respect among the group members for each other's discipline (hence, the inclusion of C, EE, EC, and PS on the list of 10), or at least reduce misconceptions and hostility. Yet the maintenance of vested interest is a curious phenomenon which, by the way, lends efficacy to the exercise. For if the individuals assembled for a two-hour experiment can be suspected of lacking commitment to the task, much less its solution, their professional socialization draws them into the task to defend, at worst, their discipline, and at best, their ego. This is where differential status comes into play. Will junior professors denigrate their own disciplines, and aggrandize others, particularly when the others are physical sciences? Similarly, will senior physical science professors try to compensate for their apparent advantage by inflating the importance of social sciences, i.e., ranking them high and then justifying the ranking (anthropology and economics were so "elevated" by the EE in this session)? What one notices is a willingness to entertain different assumptions and explanations (many of the latter were patently "wrong", i.e., they misconstrued the esoteric content, focus, or methodology of a discipline). L-C pointed out that "successful" groups expose such differences early in their existence, talk them out, and reach workable consensus--strategies which are not only goal- or product-oriented, but also process-oriented.

The message of this experimental session is that mechanisms for communication must be consciously defined and enforced. Certain biases must be recognized by all; certain modes of operation must be enforced. Productivity stems from such social control, but that control rests precariously on an intellectual and emotional foundation.

III. CONCLUSIONS

Our chief interest in conducting micro - TA experiments was to augment the findings of the earlier analyses of integration with information on process within interdisciplinary groups, i.e., how is integration achieved and under what conditions? An experimental approach was a logical derivation from the retrospective data compiled on key events and from key project personnel. The findings we have reported on the two experiments are exploratory and impressionistic. Nonetheless, they reinforce and amplify many of the survey results concerning group performance (process) in general and integration (product) in particular. Six factors warrant brief recapitulation:

1. The leadership role showed no variation across disciplines. That is, individuals playing this role are responsible for completion of the task and coordinated the team's work on it. The leader's creativity suffered, however, until he resumed playing the role of team member in subsequent sessions.

2. Early and effective bounding "freed" team members to concentrate on the substance of the problem, allowing them to meld their efforts into a single analysis and proposed solution.

3. Prior experience in team, and especially multidisciplinary, research was the outstanding team characteristic which facilitated the process of integration.

4. An "all channel" communication pattern, borne of democratic leadership, characterized the interaction in all sessions. Only at the sessions' end, when team members separated to summarize component sections of the final report, did the interaction assume a "hub and spokes" ' pattern of communication. The reports tended to reflect this lack of integration despite the interdisciplinary process that preceded the actual writing.

5. Iteration was, for the most part, a casualty of insufficient time in the sessions. Hence, individual and provisional analyses were not internally interrelated well at all.

6. Finally, epistemological distances among the members of teams A and B were minimized, if not suppressed altogether, for sake of group unity. Team C was compelled to discuss their distances and divergences of perspective. The traditional pecking order which emerged from this session was based on rigor and quantification, a finding which speaks loudly to the twin issues of team composition and disciplinary barriers in TA. These issues would be of acute importance, for example, in social impact assessments.

None of the three socio-cognitive modes of integration seemen to "interact" with the content of the problem to be solved. Yet common group leraning (CGL) in which the solution is based on the shared knowledge of the team, was by far the most popular mode. The de-emphasis here on individual expertise combined with constricted time minimized the technical aspects of solutions and the prevalence of any one disciplinary view. Modeling was of the conceptual "boxes and arrows" variety, but in the process of generating such models the teams reverted to a CGL mode. Negotiation, featuring individual expertise which is eventually integrate without diluting its technical content, was the most difficult mode for the teams to adopt. Team B balked at the prospect, opting for dividing the problem by parties-at-interest rather than by discipline, and proceeding by CGL. Even our intervention to promote negotiation was resisted. Team C, however, adopted negotiation as its functional mode without being instructed.

Clearly, TA as interdisciplinary team research involves more than a problem, human resources, and a local organizational context. It involves the values, experiences, styles, and perceptions of team members. Recognizing this, one can design appropriate group experiments. Indeed, our data suggest that such simulations reveal much about group process and individual behavior. To test the validity of such findings, however, our design must be adapted to natural settings and "genuine" teams engaged in TA projects. We shall mention only two design possibilities here.

The first possibility is a monitoring of three independently-funded assessments of the same topic in which iteration would be required and one of the three socio-cognitive modes of operation would be assigned to each project. Within these constraints, leadership behavior, bounding, and communication within the team could be closely observed. Such a quasi-experiment would bridge the retrospective survey and simulated laboratory approaches.

Another possibility is to pursue the process of negotiation among disciplinary experts, again on their home turf, but perhaps with specially developed exercises to elicit psychological, value, and epistemological differences which represent potential barriers to interdisciplinary cooperation, communication, and problem-solving. Graduate education has never addressed the need for such understanding as preliminary to fruitful collaborative research in a team context (i.e., three or more persons). This possibility would serve to prepare for future technology assessments and related policy analyses. Moreover, it would act on the knowledge that modern research organizations, like the creative people which compose them, must change form in response to the complexity of the problems they seek to investigate and solve.

NOTES

1. At least two "observers" were present and taking notes on the proceedings at each session. No electronic recording, however, was made.

2. At several points in the sessions of team B, democracy deteriorated into a more chaotic laissez-faire state, but the group moved to restore "order" by appealing, for example, to the constraint of time.

3. Quantitative and formal models were quickly abandoned, replaced by verbal and qualitative conceptualizations of sectors, flows, feedbacks, etc.

4. One underlying value orientation which surfaced was anti-big business, but political and ideological productivities otherwise remained latent. Professionalism dominated the discussions.

5. In preparing the reports, a division of labor often arose in which each team member was responsible for a part of the report. With time running short, iteration was precluded and the report components were simply given to the leader. A "hub and spokes" communication replaced the former all channel pattern and the level of group interaction deteriorated. The leader, because of the lack of time, typically functioned as an editorial coordinator in rationally juxtaposing the component analyses and often editing the introduction and adding appropriate conslusions. This fact made the final reports appear more a collection of fragments than an integrated whole. Thus the effort at integration was negated in the final phase, a finding consistent with the project's survey results.

6. An interim meeting with Dr. Pat Johnson, NSF monitor of the grant, also influenced our decision to design a second experiment.

7. This composition was typical of the 24 TA teams studies where only 3 of the project PIs were economists or social scientists. Most of the team members representing social science disciplines were of junior status.

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ADDENDUM

Excerpt of Instructions Distributed to Team Members at First Experimental Session

1. As a member of a group of 5 professionals representing a diversity of disciplines and perspectives, we request you to spend 4 hours performing a micro technology assessment (TA). A TA is an interdisciplinary study to determine the full range of consequences on society of the introduction of a new technology or the modification of an existing technology. These consequences include economic, environmental, social, institutional, political, legal, and technological impacts. In addition, TA also considers the full range of policy options for dealing with the consequences. A micro TA is a small scale study which does not have the depth of analysis or breadth of a full scale assessment.

   A typical procedure consists of the following steps:

   1. Bound the slope of the study (i.e. clarify the scope and depth of the effort) and identify those parties who have an interest in the technology being assessed together with the nature of their interest.
   2. Grasp the salient features of the technology and its social context together with some notion of their future development.
   3. Identify, analyze, and evaluate the important impacts of the technology (e.g. economic, environmental, social).
   4. Analyze the relevant policy options for dealing with these impacts and the consequences of these options.

   Ideally a TA is a truly interdisciplinary effort in which the various disciplinary and social perspectives involved are well integrated in the project output.
2. Each member of the group will receive in addition to these instructions a package of material dealing with the technology to be studied. This will serve as introductory reference materials. Of course the members of the group are free to develop and use any other material they wish, e. g. library documents.
3. One member of the group will be designated as leader. The leader's main responsibility is to insure the production of two documents. The first of these is a short report of the project output which may be handwritten. This should represent the group's best efforts to perform the micro assessment as if it were a real project for a real client. As a suggestion it may be appropriate to take notes throughout the session so that material from which to prepare the report will be at hand. The second document to be prepared is a

statement of procedures based on the group's experience. This should be written as an aid to a similar group asked to solve a similar problem with similar instructions (e.g. when the statement could include plans for the division of labor and suggestions for patterns relating isolated research and group interaction).

4. Except for following the instructions, the group may adopt whatever procedures it chooses to perform the micro assessment.

5. In this session you will be told to follow either instruction 5A, 5B, or 5C.

5A. The group will use common group learning as the basis of its report. By Common Group Learning we mean knowledge shared by the group developed in the course of performing the micro assessment. It represents the "lowest common denominator" of the group's effort since none of it is the exclusive property of any individual or subgroup.

An example may help you focus on what this means. In discussing a procedure followed by a successful TA group, we are aware that you cannot follow it verbatim in a 4 hour session. However, it should give the flavor of the group learning process. The procedure is roughly this:

1. Focus as a group on the problem to effect a preliminary bounding, i.e. setting the limits and form of the study.
2. Divide up the problem by individual expertise and interest. Each individual group member does a preliminary analysis on his part of the study.
3. Reassemble as a group to criticize each other's efforts.
4. Redo the individual researches in the light of criticism. Typically a different person will redo each part, often one with no initial expertise.
5. Iterate
6. Effect closure, i.e. reach consensus on what the final report shall contain.
7. Produce a final report based on group knowledge. Group jointly authors entire report.

5B. The group will use a model with supporting data developed within the group, but not necessarily by the entire group jointly, as the basis of its report. By model we mean a representation of a real world situation which is less complex than the actual situation. The purpose of this simplification is to facilitate the identification of important relationships and to allow their meaningful analysis. An example of a model used in a TA on No Fault Automobile Insurance is attached. Note that this model is not fully comprehensive -- several significant classes of impacts appear to be omitted. This is a problem endemic to modeling. (Clearly there will not be time to develop a computerized model.) In developing the model, the group needs to consider:

1. The specification of important relationships affecting the subject of the assessment
2. The data inputs which describe the relationships
3. The useful outputs which may be anticipated from applying the model.

These three entities should be involved significantly in the report.

5C. The group will use expert analyses interrelated via the process of negotiation at the basis for its report. For example, after the problem is bounded, it is then divided by expertise and interest. The expert analyses are prepared. Then the group attempts to develop appropriate boundary conditions and bridging mechanisms to relate the various analyses. The process is iterated until it converges into a report.

By way of an example, on one TA a lawyer upon reading an economist's analysis said that the analysis lacked institutional considerations which would help effect a bridge between the economic analysis and other parts of the project. He discussed the problem with the economist who redid his work to include these considerations.

APPENDIX E

A PROFILE OF RESPONDENTS

In the course of our work we interviewed 55 persons who had participated in one or more of the 24 TA projects in our sample. Of these, five participated in two TAs so that the total number of interviews relating to the assessments was 60. Of the interviews, 29, with 26 respondents, were from phase 1 projects while 31 interviews with 29 respondents were from the phase 2 projects. The distribution of interviews per project was from one to five. Figure E-1 shows the distribution of interviews per project. On 3 projects we spoke with only one individual, the principal investigator. In these cases, other information, such as published work, briefings, and interviews with non-participants who were close to the study, was used to determine whether the interview results were reliable. In all cases the external indications agreed with the substance of the interviews.

Of the 55 individuals we interviewed, 4 were women. Only one principal investigator was a woman. Relatively few of our respondent interviewees, 15 of 55, were junior in terms of their positions within their organizations. Four were junior faculty, three were on academic research staffs, two were graduate students, and six were junior staff members of a contract research organization. Not surprisingly, no principal investigators were in junior positions.

The positions of our respondents varied, but were more concentrated at the top and on the core team. Of the 55 respondents, 25 were classified as principal investigators or project managers, 21 were core team members, and 9 were otherwise involved. On the 24 assessments we studied, we identified a total core team population of 105, distributed as in Figure E-2. Thus we were able to interview 46 core team participants. However, since 5 of these were on the core team of two of the projects, we actually interviewed 51 of the 105 core team participants, or approximately half of the total number. The sample is definitely biased toward principal investigators. While this may not be desirable in the abstract, it remains that in some cases the PI was the only person who was thoroughly knowledgeable about the project, and in many others he/she knew significantly more about what was going on than anyone else. However, extremely valuable perspectives and insights were provided by many of the other respondents. Some intriguing insights and valuable information came from peripheral participants.

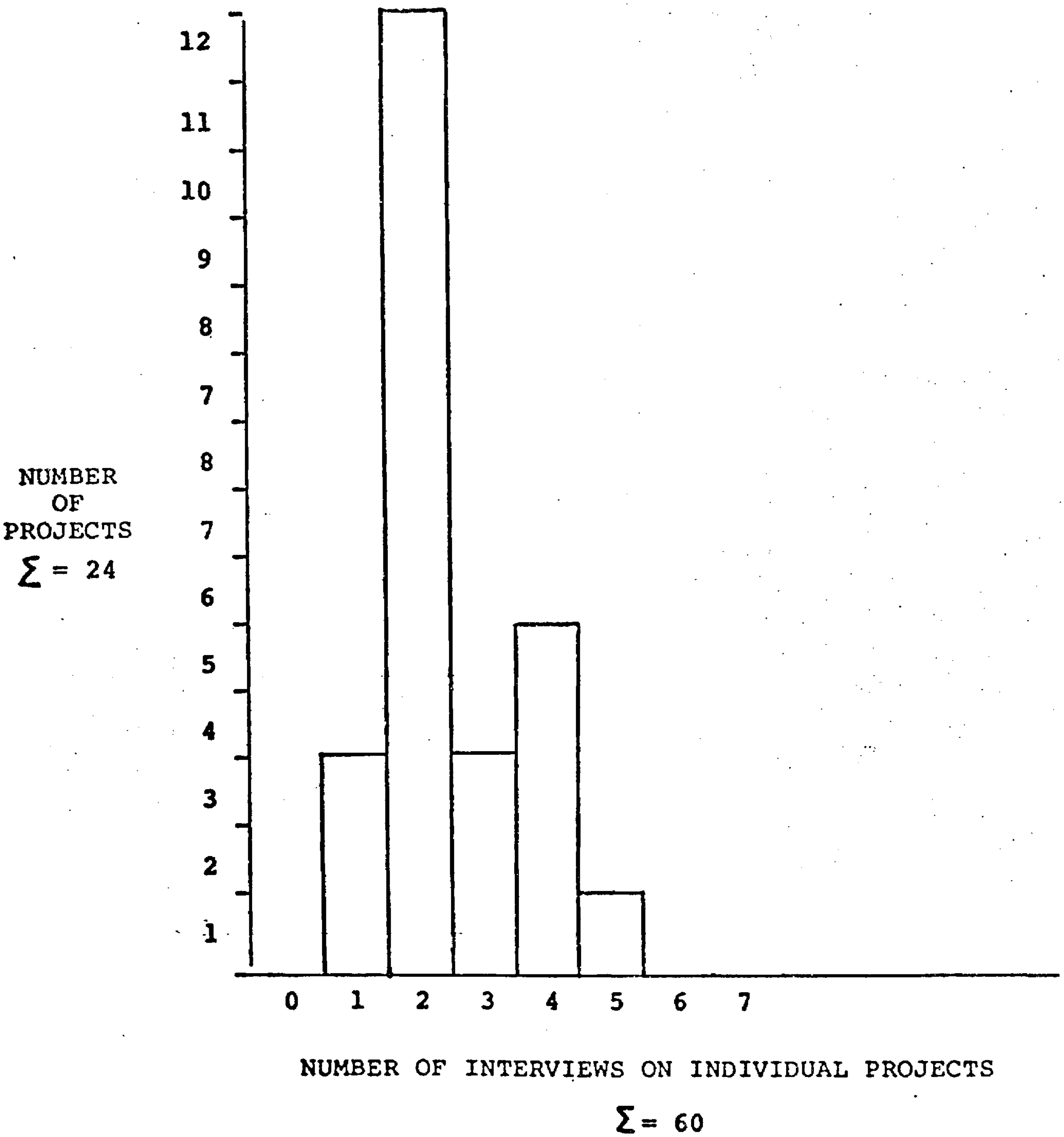

FIGURE E-1 - DISTRIBUTION OF INTERVIEWS PER PROJECT

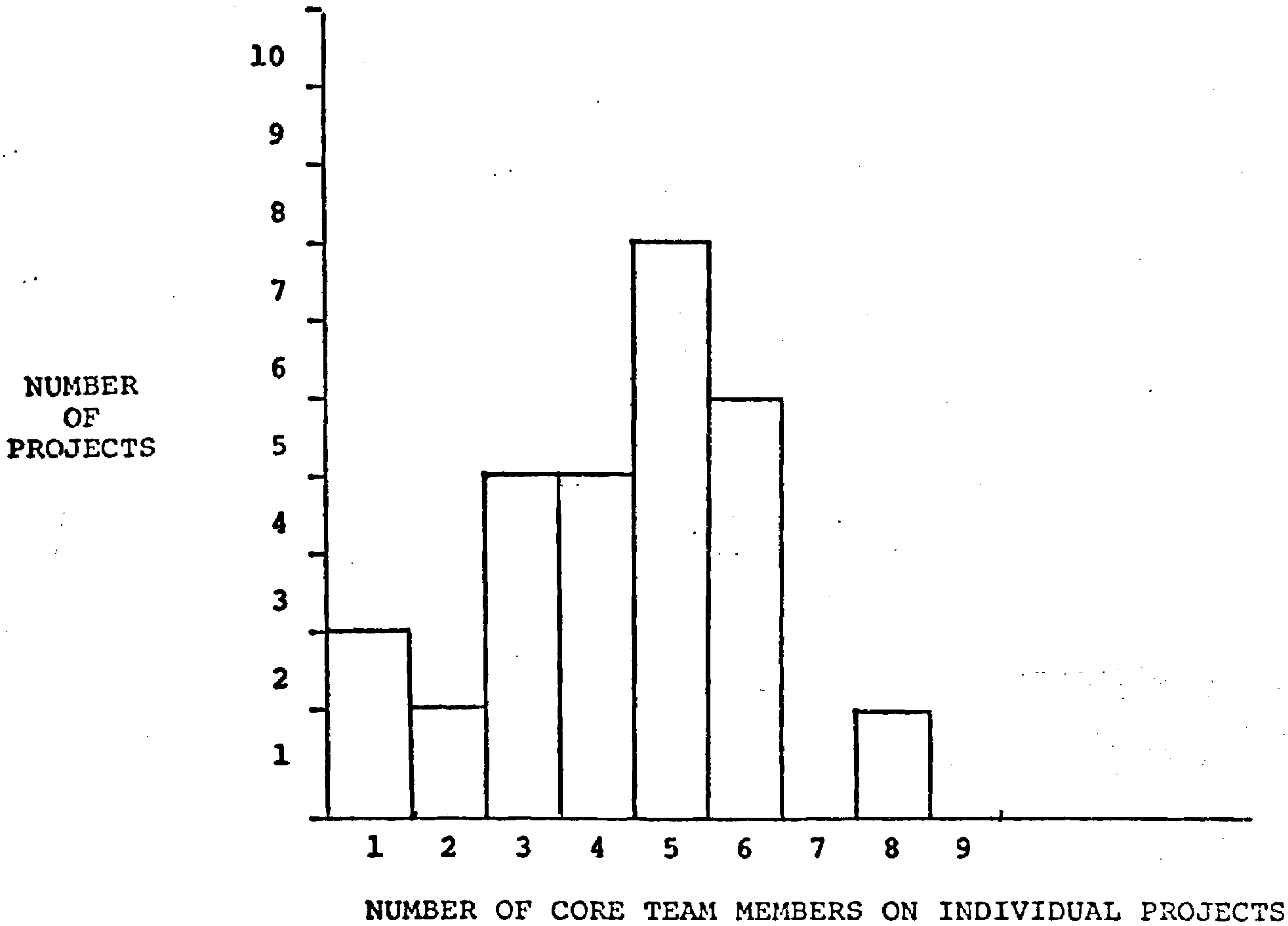

FIGURE E-2 - DISTRIBUTION OF NUMBERS ON CORE TEAM OVER 24 TAs

Table E-1 indicates the specific backgrounds of the core team members as we recorded them. Of course, individuals who were involved in two projects were counted once for each project. Table E-2 summarizes this information in more aggregated categories. A number of observations can be made from this information. Of 81 core team participants 14 had more than one disciplinary or professional specialization. Of the 24 principal investigators/project managers, 9 had more than one specialization. Natural scientists and persons classed as "systems" tended to serve most commonly as principal investigators. Engineers, social scientists, economists, lawyers, and others tended to be less common as PIs.

Of the incentives for participation in TAs which we considered (see Figure E-3), there was great similarity among the items mentioned by principal investigators and other participants. The major items mentioned by the PIs as incentives for participation in the TAs were interest in technology assessment (noted 21 times as first, second, or third influence), interest in the topic under assessment (15), generation of new contracts (15), and job rewards (12). For the team members the most popular incentives were interest in technology assessment (18), interest in the topic of the assessment (16), the learning experience (13), job rewards (13), and doing professional quality work (11).

TABLE E-1

TOTALS ON THE 24 TAs

PI's N (number of these with multidisciplinary backgrounds)	All others N (number of these with multidisciplinary backgrounds)	Discipline
1	2	AE
0	4 (1)	EE
1 (1)	3 (1)	CE
1	2 (1)	IE
0	3	ME
0	1	ChE
3 (2)	4	Physics
7 (3)	0	Chemistry
0	3 (2)	Biology
1 (1)	1 (1)	Environment
1	1	Meteorology
0	2 (1)	Mathematics
2 (1)	15 (3)	Economics
2 (1)	5	Pol. Science
0	7 (2)	Sociology
0	4 (1)	Social Psy.
0	3 (1)	Psychology
1	8 (1)	Law
9 (5)	6 (2)	Systems
3 (3)	3 (2)	TA
0	5 (3)	Planning
1 (1)	6 (5)	Business Adm/ Public Adm.
0	5	Miscellaneous (technical writing, etc.)

TABLE E-2

PI's N*(number of these with multidisciplinary backgrounds)	Others N (number of these with multtdisciplinary backgrounds)	Profession
3 (1)	15 (3)	Engineering
12 (6)	11 (4)	Natural Science/ Math
2 (1)	15 (3)	Economics
2 (1)	19 (4)	Social Science (not Economics)
1	8 (1)	Law
13 (9)	25 (12)	Systems, Professional, Miscellaneous

*People with multidisciplinary backgrounds are counted once in each discipline.

New contracts-grants

"Sold time"

Publication--disciplinary

Publication--interdisciplinary

Interest in technology assessment/interdisciplinary research

Interest in the topic of assessment

Learning experience

Professional "quality" work

Job rewards (financial reward, retention, promotion)

Figure E-3 - Incentives for Participating in TAs

APPENDIX F

MULTIVARIATE CAUSAL ANALYSIS

INTRODUCTION

As described elsewhere in this report (Section ID), various data were gathered on 24 TA studies. These data included scaled and open-ended interview items with various participants in these TAs and a series of scaled ratings by ourselves of the products of those study efforts. The data were accumulated in the context of a research strategy that:

--commenced with initial loose hypotheses to formulate an interview protocol for 12 of the TAs;

--considered the results of the first 12 TA interviews to make more specific hypotheses, and a resultant tighter interview instrument for use on the remaining 12 TAs;

--tabulated the interview data and independently evaluated the written TA products in terms of comprehensiveness, depth of analysis, and several forms of integration.

The analyses discussed in this appendix must be seen in proper perspective--as one rather small component of our attempt to understand the processes that affected the "integration" of these TAs (recall the discussion of integration in section IC). In this larger perspective our conclusions were influenced by the distilled wisdom of others (e.g., Arnstein and Christakis, 1975), the qualitative insights of particular people interviewed, and the consideration of the 24 TAs as a collection of "case studies." The attempt at a multivariate analysis was to complement these other sources of information.

Given the two-stage research strategy, it was proper for us to look separately at the indications of the second 12 TA interviews to see if these supported the hypotheses based on the first 12. This was done, albeit it was not carried out in fine detail. In general, correlational patterns were similar, based on visual inspection of key correlations in the overall matrices (e.g., with overall substantive integration as in Table F1). Given the complexity of our model (Figure F1 or Figure 2 in the report), it was deemed more sensible to use all 24 cases for the present analyses to enhance the degrees of freedom. This also required more subjective scaling on the first 12 TA interviews to make items compatible with the later interviews. Rossini and Porter prepared these and cross-checked them on all joint interviews (essentially 10 of the 12 TAs).

The intent of these multivariate analyses was to better understand the influences on integration and to suggest how one might improve the integration of TAs. We settled upon our rating of overall substantive product integration as the most salient dependent variable for these intentions. We included a large number of measured independent variables (from the categories of Figure F1 as potentially important influences. Furthermore we tried several different analytical approaches seeking "robust" conclusions.

SPECIFIC APPROACHES

The analyses used included:

--several multiple regressions,

--alternative factor analysis/regression formulations, and

--construction of several path analysis models.

Various permutations of measured independent variables, sometimes collapsed into factors, were examined in each of these formulations. The following are exemplary:

1) Integration was regressed directly on a set of 21 of the most hypothetically significant measured independent (project) variables.

2) A large set of variables were split into six factor categories[1]

[1]Analysis of the observed correlations among the measured independent variables and integration led us to trim the hypothetical "factors" (Figure F1) to the six that appeared most likely to exert strong and direct influence on integration--leadership, team characteristics, bounding, iteration, communication, and epistemological factors.

Table F1

Examples of Pearson Correlations of Overall Substantive Integration with Selected Important Variables

	Cases 1-24	Cases 13-24
Systemic Integration	.78	.92
Leadership Style	.49	.51
Satisfactoriness of Study Bounding	.46	.40
Number of Times Whole Study Iterated	.47	.56
Character of Communication Pattern during Report Writing	.34	.29
Epistemological Distances Among Team Members (normalized)	.50	.39

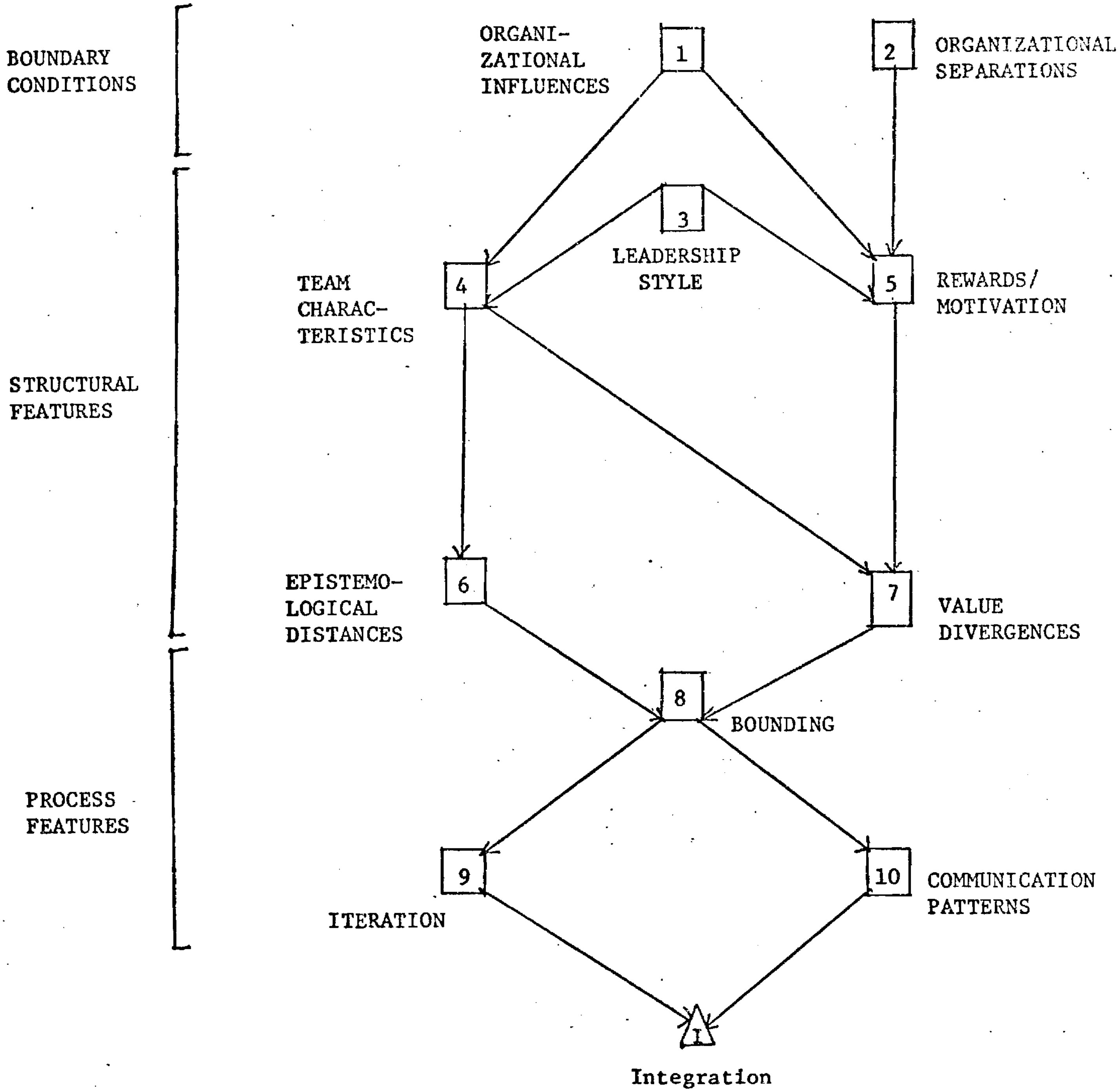

Figure F1 - A Model of Influences Upon Interdisciplinary Integration

NOTE: This schematic figure attempts to show composite direct and indirect influence patterns; it does not distinguish every relationship. For instance, epistemological distances may directly affect communication patterns, but no direct linkage is displayed.

and the categories factored (Nie et al., 1975). The factors were rotated obliquely. Until factor scores were determinate, variables were removed from the factor categories when more than one variable behaved similarly by eliminating the hypothetically less significant variables. This produced eight factors, as two factor categories bifurcated on analysis. These eight factors were then introduced stepwise into a regression with integration.

3) A set of only the 21 most hypothetically significant variables were factored within the six factor categories using the procedure of (2). As in (2), eight factors were produced, but the factors which bifurcated were different than in (2). These were then incorporated into a stepwise regression with integration.

4) The variables used in (3) were divided into the factor categories as in (3), except that the weighting was done by the project team on considerations relating to the hypotheses developed on the project. Six factors were constructed and entered into a regression with integration.

In every case problems arose because of the small number of cases being considered. In the case of the first regression on measured variables (1), the absence of data for some variables in some cases reduced the total number of degrees of freedom to 12. When the variables were regressed stepwise on integration, a singularity developed after the third variable was entered. A compromise was developed which excluded the three iteration variables and two of the eight communications variables. This increased the degrees of freedom to 17. Stepwise regression on integration indicated three variables entering with an F value greater than one.

$$\text{Integration} = -.00242 + .53\,(\text{Epistemological Distances on Team}) + .60\,(\text{Leader Style}) + .37\,(\text{Significance of Epistemological Gaps}).$$

For this analysis $R^2 = 0.57$ and R^2 (adjusted)[1] = 0.45.

In the second case, stepwise regression on the eight factors produced an $R^2 = 0.68$, but R^2 (adjusted) = -0.61. This latter (nonsensical) value is due to

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[1] Adjusted R^2 is an R^2 statistic adjusted for the number of independent variables in the equation and the number of cases. It is a more conservative estimate of the per cent of variance explained, especially when the sample size is small. The logic of this measure is based on the following conceptual formula for R^2 (Nie et al., 1975:358):

$$R^2 \text{ in the population} = 1 - \frac{\text{error variance in Y in the population}}{\text{total variance in Y in the population}}\,.$$

instability associated with the small number of cases as compared with the number of factors considered. The maximum value of R^2 (adjusted) came after the first two factors of the stepwise regression. One of these factors was related to leadership, while the other reflected epistemological considerations. Here $R^2 = 0.52$ while R^2 (adjusted) = 0.40.

Integration = 29.27 + 7.53 (Epistemological Factor) + 2.90 (Factor relating to Leader's Emphasis on Integration).[1]

In the third case using only the 21 variables factored into eight factors, after the stepwise regression of all factors on integration, $R^2 = 0.53$ while R^2 (adjusted) = -0.41. Again the relatively small number of cases and the large number of factors made explanation of the variance problematic. The greatest R^2 (adjusted) in the stepwise regression was 0.19 (corresponding to $R^2 = 0.39$) with three factors, one relating to epistemological considerations and two to communication variables.

Integration = 26.22 + 3.70 (Epistemological Factor) + 6.04 (Communications at Project Extremes Factor) + 5.84 (Communications in Mid-project Factor).

In the fourth case, with the 21 variables grouped in the six factor categories with their weights determined on the basis of hypothetical understanding, $R^2 = 0.50$ and R^2 (adjusted) = 0.22. With two factors representing epistemological considerations and iteration in the regression, $R^2 = 0.45$ and R^2 (adjusted) = 0.38.

Integration = .042 + .61 (Epistemological Factor) + .58 (Iteration Factor).

In our efforts to understand the causal relationships between integration and the factors affecting it, it was decided to develop a path analytic model for integration based on the factors in (4). There were a number of reasons for this. First, this formulation explained a reasonably large fraction of the variance of integration (R^2 (adjusted)). In cases where a higher proportion of variance was

[1]This equation and the one immediately following use unstandardized regression coefficients. In the other two equations the coefficients are standarized.

explained, the variables were from a limited number of factor categories. Most importantly, in the chosen case, the factors were based on the hypotheses developed early in the project. The lack of a large number of cases led to a tradeoff between explanatory power and richness of causal understanding. We opted for the latter, as our goal was, in addition to understanding how integration was achieved, to make action recommendations on how to achieve it. A causal model makes it possible to understand how such change can be affected.

It is important to understand in what follows that, because of a lack of cases and the exploratory nature of the study, nothing has been proven. However, plausible model which can serve as a reasonable basis for action or further study has been developed. In essence, the path analysis might be interpreted as saying that the observed data are not inconsistent with the developed model. They may well be somewhat more consistent with another empirical model, but that is not compelling logic because of the likelihood of serious measurement errors and the quite small, and therefore rather unstable, sample.

CAUSAL PATH ANALYSIS

We now offer a brief description of path analysis to those who may be totally unfamiliar with it. Path analysis (Nie et al., 1975; Duncan, 1975) is a form of causal modeling which depends on two assumptions. Weak causal ordering among a set of variables means, that for variables ordered with $X_i \geq X_j$, that X_i may or may not influence X_j causally, but that X_j cannot so influence X_i. Causal closure among a set of variables means that for $X_i \geq X_j$ the observed covariation between X_i and X_j may be due to the causal dependence of X_j on X_i, their mutual dependence on outside variables, or some combination of these.

For example, consider a three-variable system of X_3, X_2, and X_1. A general model which specifies a weak order, say, $X_3 \geq X_2 \geq X_1$, and causal closure, can be expressed either by path diagrams, as in Figure F2, or by a system of linear

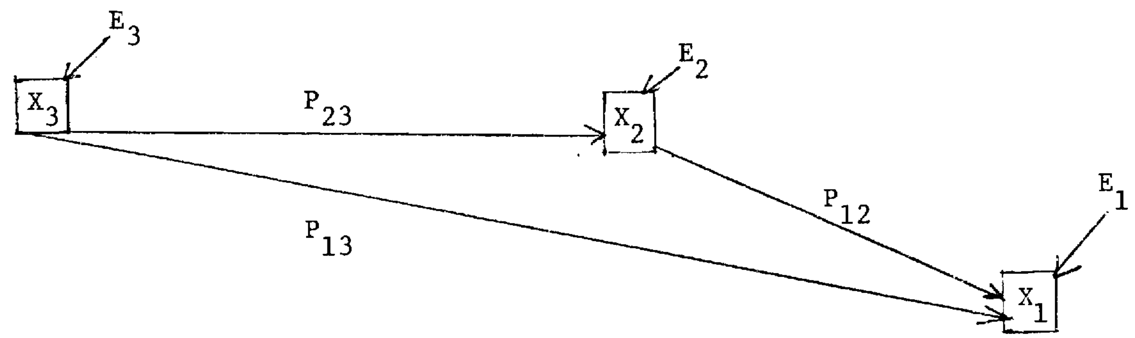


Figure F2. Path Diagram with Three Explicit Variables

$$X_3 = E_3$$
$$X_2 = P_{23}X_3 + E_2$$
$$X_1 = P_{13}X_3 + P_{12}X_2 + E_1$$
$$\mathrm{cov}(E_3,E_2) = \mathrm{cov}(E_3,E_1) = \mathrm{cov}(E_2,E_1) = 0$$
$$\bar{E}_1 = \bar{E}_2 = \bar{E}_3 = 0$$

equations (below Figure F2). In those equations, variables are assumed to be measured as deviations from their respective means. The E_i are the latent variables.

These two ways of formalizing the underlying assumptions represent the general model in the sense that any one of the paths can be null, and equivalently, any one of the P_{ij} can be zero. Inspection of the structural equation model indicates that P_{23} may be estimated from the regression of X_2 on X_3,

$$X_2' = B_{23}X_3$$

and P_{13} and P_{12} may be estimated from the regression of X_1 on X_2 and X_3,

$$X_1' = B_{13}X_3 + B_{12}X_2$$

In general, given n variables with the weak order $X_n \leq \ldots \leq X_2 \leq X_1$, estimation of all the path coefficients will require (n - 1) regression solutions, taking each of the (n - 1) lower-order variables as the dependent variable in succession and all of its higher-order variables as predictors.

Turning to our causal model, note again that we began with the influence diagram, Figure F1, and considered areas where there were indicators with significant correlations. Using the hypothesized influences and initial correlations, we eliminated a number of areas, primarily boundary conditions and those where our data were not robust. In our model building we used six composite independent factors and a single dependent factor, overall substantive integration, INT. The independent variables are as follows:

LEAD reflects the leadership factor. It is an equally weighted composite of the leadership style index discussed above and the respondents' evaluation of the team leader's emphasis on integration. The Pearson correlation between these two variables is .14, which is not unreasonable since there is no strongly positive hypothetical connection between these variables.

TEAM reflects various characteristics of the project team. It is a composite of core size, coded binary (with 3 to 5 preferable to any other size) weighted twice; plus the respondents' evaluation of TA-like joint prior work by the team members; minus an indicator of the degree of changes on the project team during the life of the project. Not surprisingly, team size correlates strongly with neither of the other indicators. Prior joint work and changes correlate negatively with $\rho = -.43$.

BOUND is an indicator of bounding. It is composed of indicators of early setting of limits and of form, in addition to an indicator of satisfactoriness of bounding weighted at two. The intercorrelations of these three variables vary from $\rho = .52$ to $\rho = .60$.

COMM indicates the communications patterns and level of communication during the project. It is composed of the index of communication patterns, from wheel to all-channel, weighted at 7; plus 7 indices weighted at one. These are the relative level of interaction during proposal preparation, early phase, middle phase, latter phase, and final report writing, as well as the respondents' judgment as to frequency and importance of informal group meetings, and frequency of formal meetings.

ITER indicates extent of iteration of the research. It is composed of equally weighted indicators of the extent of iteration of the parts of the assessment, and the extent and number of times the whole TA was iterated. The intercorrelations here vary from $\rho = .50$ to $\rho = .77$.

EPIS deals with epistemological gaps on the project. It is composed of the equally weighted indices of disciplinary disparity the project team as normalized for the number of team members, and the self-rated significance of epistemological gaps. The correlation between these two is negative, $\rho = -.21$.

Comparing the influence diagram (Figure F1), including the indirect causal links which were not shown, with the constructed factors described above, and making use of the intercorrelation matrix of the seven factors (Table F2), we worked through a series of alternative path models. We refined progressively until we reached the model shown in Figure F3. Table F3 indicates the decomposition of the sources of covariance shown in Figure F3.

While this model has the limitations on its data described earlier, its causal links are plausible, and it accounts for a reasonable amount of the observed variation in integration. A brief discussion of the causal links and the discrepancies is contained in the text of the paper.

References

Arnstein, S.R. and A.N. Christakis, 1975, Perspectives on Technology Assessment, Jerusalem, Science and Technology Publishers.

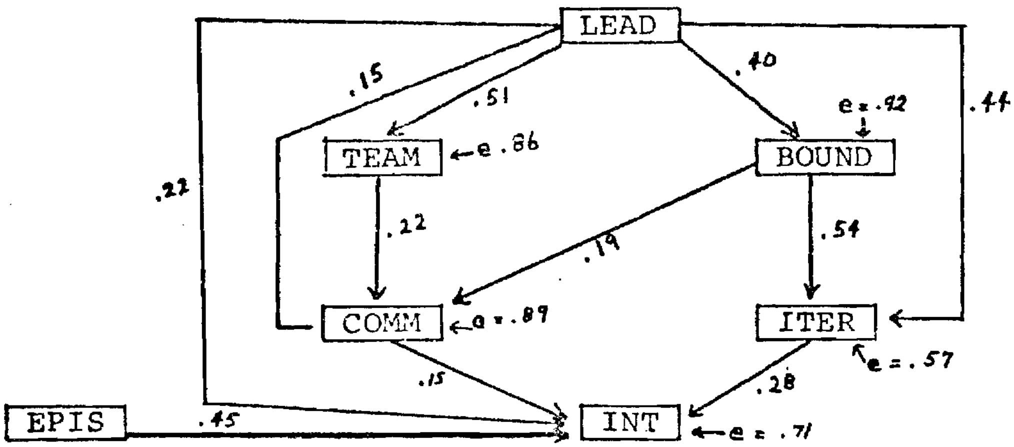
Duncan, O.D., 1975, Introduction to Structural Equation Models, New York, Academic Press.

Nie, N.H., et al., 1975, Statistical Package for the Social Sciences, Second Edition, New York, McGraw Hill.

Table F2

Intercorrelations of Factors in Causal Model

	INTEGRATION	ITER	EPIS	BOUND	COMM	TEAM
ITER	.54453					
EPIS	.43947	.08302				
BOUND	.31848	.71102	-.15738			
COMM	.34803	.51837	-.05701	.36316		
TEAM	.22195	.22879	-.12647	.51813	.39599	
LEAD	.40007	.65538	-.13124	.39700	.33879	.51002



$$e = \sqrt{1-r^2}$$

Numbers along arrows represent the path coefficients, P_{ij}

FIGURE F3 - A CAUSAL MODEL FOR TA INTEGRATION

.E F3 DECOMPOSITION OF COVARIANCE FOR CAUSAL MODEL FOR TA INTEGRATION

RELATIONSHIP	TOTAL COVARIANCE A(r_s)	CAUSAL DIRECT [P_s]B	CAUSAL INDIRECT C	CAUSAL TOTAL D=B+C	NON-CAUSAL E	DISCREPANCY A-(E+D)
LEAD-TEAM	.51	.51	0	.51	0	0
LEAD-COMM	.34	.15	.08	.34	0	0
LEAD-BOUND	.40	.40	0	.40	0	0
LEAD-ITER	.66	.44	.22	.66	0	0
LEAD-INT	.40	.22	.23	.45	0	-.05
TEAM-COMM	.40	.22	0	.22	.18	0
TEAM-BOUND	.52	0	0	0	.20	.32
TEAM-ITER	.23	0	0	0	.50	-.27
TEAM-INT	.22	0	.03	.03	.20	-.01
BOUND-COMM	.36	.19	0	.19	.17	0
BOUND-ITER	.71	.54	0	.54	.18	-.01
BOUND-INT	.32	0	.18	.18	.16	-.02
COMM-ITER	.52	0	0	0	.28	.24
COMM-INT	.35	.15	0	.15	.22	-.02
ITER-INT	.54	.28	0	.28	.23	.03
EPIS-INT	.44	.45	0	.45	0	-.01